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MACHINE DRAWING

BOOK I. 3RD EDITION.

T. JONES   T. G. JONES

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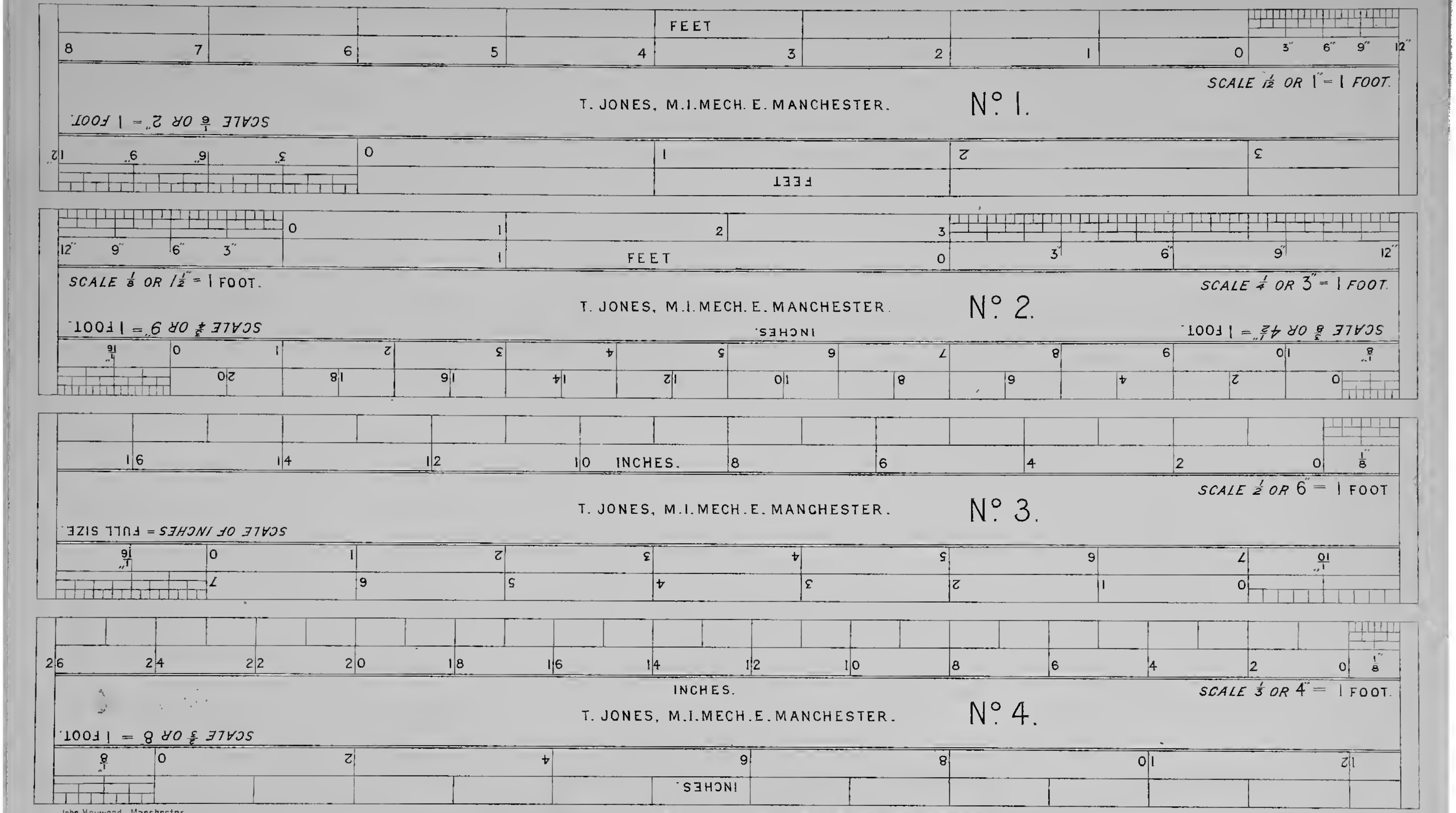
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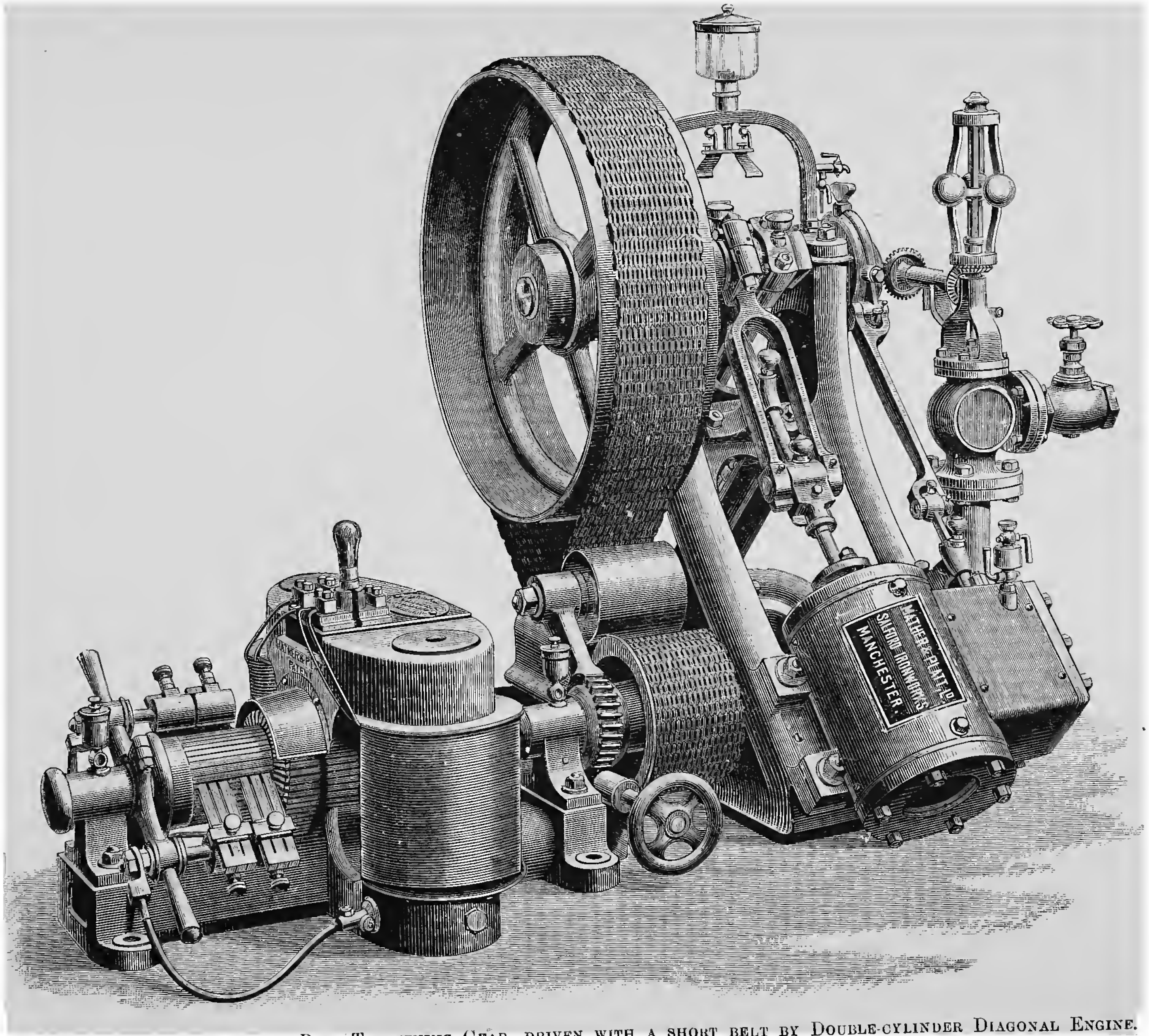

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MACHINE DRAWING,

FOR THE USE OF

ELEMENTARY AND ADVANCED

STUDENTS IN SCIENCE AND TECHNICAL SCHOOLS AND COLLEGES,

BY

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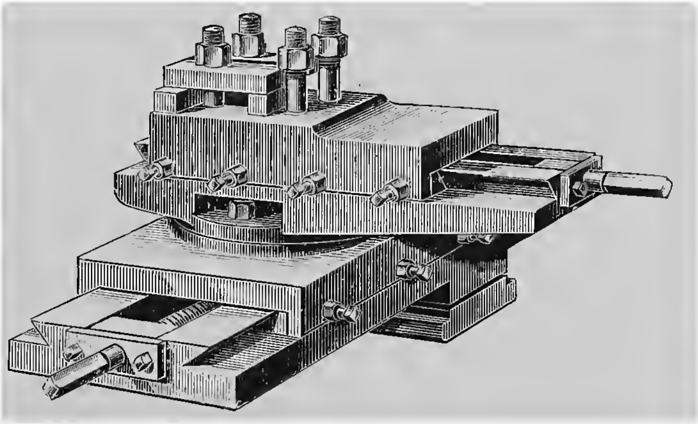

THIRD EDITION

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PREFACE.

IN issuing this book to the public the Authors feel that no apology is necessary. They have long felt the want of a book on Machine Drawing which would furnish, at a reasonable price, *properly finished* and complete drawings of details taken from the most recent practice.

The Authors believe that the best way to encourage the student to make good drawings is to place good ones before him as copies; and they venture to think that they have succeeded in doing this. The method so often employed in cheap books of requiring the student to draw complete and accurate drawings from incomplete and inaccurate copies is not good; such copies may well serve as tests of knowledge already acquired, but cannot be considered the best means of imparting it.

Exercises are given which require the student to test his power of making original drawings, by deducing from the complete views given, others which are not given. The descriptive letterpress, notes and exercises furnished with each drawing, and the perspective illustrations will be found of great assistance for this purpose.

The drawings are not arranged in order of difficulty, since details used for the same purpose, but of different design, are grouped. The teacher should select work suitable to the ability of the student. Drawings for the most elementary, and for the most advanced, are comprised in the following pages.

The *proper* method of projecting the various views—one from the other—has been adopted in all cases. This is fully explained in the notes to Plate II.

An important feature is the introduction of perspective illustrations of some of the details. These are next in order of value to the use of models. Since the latter cannot be easily obtained, the illustrations form an excellent substitute for them.

In many cases graphic methods are employed to obtain well known proportions of machine parts; for instance, the method of finding the diameter and pitch of rivets given on Plate IV. may be specially noted.

The Authors desire to express their thanks and indebtedness to several local engineers for their kindness in supplying detailed drawings of some of their products. To Messrs. Kendall & Gent for the lathe details, to Messrs. Smith and Coventry, Ld., for details of the adjustable hanger and Sellers' shaft coupling, and to Messrs. Mather & Platt, Ld., for the woodcut of engine and dynamo used as frontispiece, and also for details of their piston.

The thanks of the authors are also due to Mr. John Heywood and his staff for the excellent manner in which the book has been produced.

THOMAS JONES.
T. GILBERT JONES.

MANCHESTER, *September, 1893.*

PREFACE TO THE THIRD EDITION.

IN this, the third edition, four new plates of engine details and also a fully tinted drawing of a horizontal non-condensing engine have been added to the original book. We trust these drawings will be appreciated since they make the book more complete, and also increase the value of some of the engine details given in the earlier pages.

The advanced student may now use those details as parts of the complete engine; the slight alterations necessary to be made in the dimensions and proportions providing exercises of a most valuable kind.

The elementary student will also find his work more interesting since he will be enabled to see the position in the engine, and learn the use of the detail he may be drawing.

We thank Messrs. Stocks & Co., Engineers, Manchester, for kindly furnishing us with a drawing of the Pickering Governor.

MANCHESTER, *October, 1897.*

T. J.—T. G. J.

SYLLABUS OF THE EXAMINATIONS

— HELD BY THE —

SCIENCE AND ART DEPARTMENT IN SUBJECT II.

MACHINE CONSTRUCTION AND DRAWING.

FIRST STAGE OR ELEMENTARY COURSE.

IN the elementary stage, a knowledge is required of the simple parts only of machines in common use. Some of these are enumerated in the following list. The student should be practised in drawing them till he recognises their forms, and the object of the arrangement should be explained to him. He should also know the simple technical terms used in describing them.

A few very simple questions relating to the arrangement, proportions and strength of the simplest machine details will be set in the examination paper.

In drawing the examples set to test a student's knowledge and skill in machine drawing, it must be remembered that only a limited time is available. It is only possible to set an example to be drawn in pencil, and the points which will receive attention are, (1) accuracy of scale and projection; (2) power of reading a drawing, shown by the ability to transfer portions of the mechanism and dimensions from one view to another; (3) knowledge of machines as shown by the ability to fill in small details, such as nuts, keys, &c., omitted in the sketches given. Bearing in mind the limited time available, the student should try to make his outline clear and decisive and complete. But the diagonal lines necessary for sectional parts may be done rapidly, though neatly, by freehand if necessary.

Riveted Joints.—Forms of rivets and arrangement of rivets in lap and butt joints with single and double-riveting. Junction of plates by angle and T-irons.

Bolts, Studs, and Set-Screws.—Forms of these fastenings. Forms and proportions of nuts and bolt-heads. Arrangement of flanges for bolting.

Pins, Keys, and Cotters.—Form of ordinary knuckle joint. Use of split pins. Connection of parts by a key. Connection of parts by a cotter. Gib and cotter.

Pipes and Cylinders.—Forms of ordinary pipes and cylinders and their flanges and covers.

Shafting —Forms of shafts and axles and of journals and pivots. Use of collars and bosses. Half lap coupling. Box coupling. Flange coupling.

Pedestals and Plummer Blocks.—Simplest forms of pedestals and hangers for shafts. Form and arrangement of brass steps. Arrangements for fixing pedestals and for neutralising the effects of wear.

Toothed Gearing.—Forms of ordinary spur and bevel wheels. Meaning of the terms pitch, breadth of face, thickness of tooth, pitch line, rim, nave, arm. Mode of drawing bevel wheels in section.

Belt Pullies.—Forms of belt pullies for flat and round belts. Stepped speed cones. Drawing of pullies with curved arms.

Cranks and Levers.—Forms of ordinary cast-iron and wrought-iron cranks and levers. Modes of fixing crank pin. Modes of fixing crank shaft. Double cranks. Form of eccentrics.

Links.—Most simple forms of connecting rod ends, open or closed. Use of steps in connecting rods. Use of cotters to tighten the steps.

Pistons.—Simple forms of piston, Use of piston packing. Modes of attaching piston rod.

Stuffing Boxes.—Simple form of stuffing box and gland. Use of packing. Mode of tightening gland.

Valves.—Simple conical or puppet valve. Simple slide valve. Cock or conical sliding valve.

SECOND STAGE OR ADVANCED COURSE.

The student must be able to draw a more complicated piece of machinery than in the elementary stage. He must be able to fill in simple details (bolts, &c.) omitted in the sketches given. He must be able to draw separate and enlarged views of details of the piece of machinery of which sketches are given. Lastly, he must be able to answer simple questions as to the materials used in constructing machinery and the reasons of the arrangements adopted.

The examination consists of two parts: (1) Some questions on the qualities of the materials used in the construction and on the arrangement, proportions, or strength of the simpler machine details. So far as the questions involve a knowledge of applied mechanics they will be of a simple kind, and will be confined to the application of mechanical principles to specific cases of designing; (2) a rough sketch of some simple machine or portion of a machine will be given in which there are various details of bolts, joints, gearing, framing, &c., and from this a pencil working drawing, drawn to scale, will have to be produced. The remarks as to the character of the drawing in the elementary stage are also applicable to this.

Riveted Joints.—Ordinary proportions of a riveted joint for wrought-iron plates. Pitch of rivets. Conditions fixing the minimum distance of rivets from each other, and from the edge of the plate.

SYLLABUS.—*Continued.*

Mode of treating plates where three or more overlap. Forms of boiler stays.

Bolts.—Meaning of term pitch of screw. Forms of Whitworth and other screw threads. Modes of locking nuts. Ordinary proportions of nuts and bolt-heads.

Keys and Cotters.—Arrangements of key and cotter fastenings. Taper of keys and cotters. Proportions of cotter for a given rod. Modes of fixing cotters.

Shafting.—Forms of shaft couplings. Distinction between fast, disengaging, and universal couplings.

Bearings.—Proportions of an ordinary pedestal. Arrangement of footstep bearings. Modes of lubricating bearings.

Toothed Gearing.—Material of gearing. Nature and use of mortice wheels. Ordinary forms of teeth. Meaning of the terms face, flank, clearance. Relation of pitch, number of teeth, and diameter. Velocity ratio of a pair of wheels. Ordinary proportions of teeth.

Belt Gearing.—Velocity ratio of a pair of pullies. Use of guide pullies. Joints of belting.

Linkwork.—Ordinary arrangement of cranks, levers, cross-heads, connecting rods, and coupling rods.

Valves.—Lap, lead, and travel of slide valve.

The student will be required to draw to scale, in pencil, from sketches, a piece of machinery, and to make separate drawings in some cases of special details. Examples of the subjects selected to test the candidate's knowledge are given below—

Simple steam cylinder and valve chest, with steam passages.
Cross head and slide block for horizontal engine.
Air pump condenser and valves.
Force pump and valves.
Simple arrangement of gearing, pedestals, and framing.
Lathe headstock, or other portion of a machine tool.

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,, IV.—Rivets and Riveted Joints.
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,, VI.—Projections and Forms of Screw Threads.
,, VII.—Proportions of Nuts and Bolts.
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LIST OF PERSPECTIVE ILLUSTRATIONS.

Frontispiece - - - Diagonal Engine and Dynamo.

Single Riveted Lap Joint
Knuckle Joint
Pedestal
Eccentric
Connecting Rod End for Launch Engine
Crosshead for Horizontal Engine
Patent Adjustable Hanger
Loose Headstock for 8″ Lathe
Gusset Stay for Boiler
Claw Coupling
Cast-iron Crank
Connecting Rod End with Strap
Forked End of Connecting Rod
Cylinder for Horizontal Engine
Compound Slide Rest for 10″ Lathe

INTRODUCTION.

A MACHINE drawing to have any value must be accurate, and since accuracy cannot be obtained without neatness, it follows that to be neat and accurate should be the aim of the student. He should also practice drawing to scale from the commencement, since it is as easy to draw to scale as to make a drawing full size. The cardboard scales supplied may be used for this purpose. They should be neatly cut out, exactly down the line, so that all dimensions can be transferred to the drawing paper, by placing the scale in contact with it, and not by means of dividers or compasses. The latter method injures the scale, disfigures the drawing, and is much too slow.

The scales fixed for the various drawings are so arranged, that the student can get the complete drawing, with the additional views required, on a sheet of paper of half imperial size, 22″ × 15″.

Most of the drawings given are *shade lined,* which gives a very effective appearance to them. The student should not attempt to do this until he is able to make an accurate drawing, with neat lines of equal thickness throughout. The method of shade lining is explained below.

Section lines are used to show any piece cut by a section plane; these lines must always be drawn with the 45° set square. Where two pieces of material are in contact and in section, the section lines must be drawn in opposite directions.

No special method of section lining has been adopted except in the case of brass, which is used so often in connection with cast-iron. The lines in this case are alternately full and dotted. Similar lines but of coarser pitch have been used for stone.

Wrought-iron and cast-iron sections are shown in the same manner by full lines. The attempt to represent each material by a different method of section lining, leads to confusion, and spoils the appearance of the drawing. In a drawing for use in the workshop, the material of which the various parts are to be made must be distinctly *written down.* No fanciful method of section lining would be accepted.

The best way of representing the various materials is by colouring. In all cases the outside views, plans and elevations, should have only a light wash of colour, and the sectioned parts should be much darker. The centre lines of finished drawings are usually drawn in crimson lake, and the dimension lines in prussian blue; but some engineers use blue centre lines for revolving parts, such as shafts.

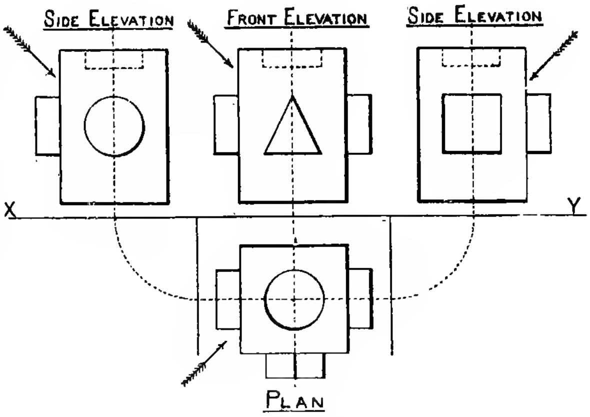
The following colours are almost universally used:—

Cast-iron and lead (elevations, &c.)	Payne's Grey	Brass	Indian Yellow
„ „ (sections)	Indigo	Copper	Crimson Lake tinged with Gamboge
Wrought-iron (elevations, &c.)	Prussian Blue	Wood	Burnt Sienna
„ (sections)	„ „	Brickwork	Crimson Lake
Steel	Purple made of Prussian Blue, tinged with Crimson Lake	Stone	Light tinge of Gamboge

It is useless to attempt here to teach the student to colour, or even to make a machine drawing; he is advised to join one of the many excellent classes established throughout the country, where he can have the benefit of the advice and assistance of an experienced teacher. A few hints are given in the notes to Plate X.

◆

SHADE LINING.



The method of shade lining a drawing is shown in the accompanying sketch. The example selected is a square prism with projecting pieces on three of its vertical faces, and a circular recess in the top face. The object is supposed to be illuminated by parallel rays of light, the directions of which make in the elevation and plan respectively angles of 45° to the horizontal and vertical planes of projections, as shown. In the *front elevation* the right hand and bottom lines are thickened, except in the elevation of the cylindrical projecting piece; because in this case the bottom line is a *contour* of the cylinder and not the intersection of two surfaces. *The contours of curved surfaces should never be shade lined.*

In the *plan* the top and right hand lines of the figure are thickened, except in the case of the cylindrical recess, where the shade line is on the opposite side; the thick line gradually vanishing at the points where lines parallel to the plan of the rays, are tangential to the circle.

The directions of the rays as shown in the side elevations are correct, because the vertical planes upon which they are projected are turned through an angle of 90°. It is usual, however, to take the projections of the rays of light in the *same* direction in all the views, plans and elevations alike. Every view therefore is shade lined, as in the front elevation given in the sketch. The appearance of the drawing is equally effective, and the making of it much simplified.* *Always place shade lines so that their thickness is outside the outline of the drawing.*

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* This method is followed throughout the book.

Plate I.—PLANE GEOMETRY.

ONE of the early difficulties, experienced by the student in machine drawing, is the joining together neatly of curved and straight lines. Practice enables the experienced draughtsman to do this, in most cases by trial, without using any construction for finding the centres of the tangent circles, or their points of contact with other circles or straight lines.

Where a circle is required to touch two straight lines, the lines should be drawn first to meet each other if possible, and the circle afterwards constructed to touch them. In inking-in the drawing, the circle or arc of circle is drawn first, and the straight lines then drawn to touch it. A few problems are given on the opposite page, showing how the centres and points of contact of tangent circles, may be obtained by geometrical construction.

Fig. 1. A circle with centre O is given with a point B on its circumference; a tangent B Q is drawn from B by drawing the radius O B and making B Q at right angles to it. **Note.—Set squares may be used for drawing lines at right angles.** A second tangent A P is drawn from the point A by joining A O, and upon A O as diameter drawing a semicircle cutting the given circle in P, the point of contact.

Fig. 2. The two lines at right angles are given, a circle of given radius R is required to touch them. Draw the lines to meet each other, bisect the angle between them by means of the 45° set square, and draw a line parallel to one of the given ones at a distance from it equal to R. O is the centre of the required circle, and perpendiculars O A and O B drawn to the given lines determine the points of contact.

Fig. 3 is worked in a similar way to Fig. 2, but the given lines are not at right angles, and the angle between them must be bisected by construction.

Fig. 4. The circle with centre O and the straight lines are given. Circles with radii R and R_1, respectively, are required to touch them. Draw any radius from O and produce it, and measure on the produced part a distance equal to R; draw a line parallel to the given one at a distance from it equal to R; with O as centre and O Q as radius, describe an arc, cutting the line in Q, the centre of the required circle; join O Q, cutting the circle in N, the point of contact with the circle. The point of contact with the line is found as before. The circle with radius R_1 is found in a similar manner.

Fig. 5. The two circles with centres O and P respectively are given, and a circle with radius R is required to touch both. The sketch explains itself.

Fig. 6. The two circles with centres O and P respectively are given, a circle is required to touch both, but to touch one at the point T. Join O T and produce it, make $S T = r$, join P S and draw T U parallel to it, meeting the circle in the point U. Draw P U and produce it to meet O T produced in Q, the centre of the required circle.

Fig. 7 shows the best method of constructing an ellipse by means of a paper trammel; given the major and minor axes. Draw the axes A B and C D bisecting each other at right angles at the point O. Cut a piece of paper with a straight edge, and mark on this edge a distance X Z equal to A O, and a distance X Y equal to C O; place the point Y on A B, the major axis, and the point Z on C D, the minor axis; then X will be a point in the curve. Any number of points may be found by placing the trammel in various positions. The curve can be drawn through the points so found, either freehand or by using a French curve. To draw a tangent to the ellipse through any point in the curve as P. Find the foci F and F_1 by measuring C F and C F_1 equal to A O or B O; draw F_1 P F P; the line bisecting the angle F P Q, is the tangent at P.

Fig. 8 shows an approximate method of constructing an ellipse by means of arcs of circles; draw the major and minor axes as before, bisecting each other at right angles.

Draw the rectangle O B E C, bisect B E in F, draw C F and E D intersecting each other in G; bisect C G by a line at right angles to it; the bisecting line meets the line C D in J, the centre, from which the arc L C G is described. Complete the quadrantal arc C L K, join K A and produce to L, join L J; the point M is the centre from which the arc L A is described; the ellipse can be completed by symmetry.

Fig. 9 shows the method of drawing and figuring a plain scale. In this case a line 2″ long represents one foot. English engineers almost universally adopt this method of stating the scale to which a drawing is made. **a″ = one foot.**

The ratio which every line of the drawing bears to the real size of the object is determined by finding the **fraction** of the scale. The fraction is always $\frac{a}{12}$; in the scale shown this will be $\frac{2}{12} = \frac{1}{6}$. Only one foot is sub-divided into inches and half inches; the divisions are figured in the opposite direction to those of the feet not sub-divided. The zero of the scale is not at the end as in an ordinary rule.

Figs. 10 & 11 show plain scales $\frac{1}{10}$ full size; one is an ordinary scale of English feet, and the other a comparative scale showing metres and its sub-divisions of decimetres and centimetres. The value of the metre is very nearly 3′ – $3\frac{3}{8}$″ English measure. The single accent denotes feet and the double accent inches; thus, 3′ – $3\frac{3}{8}$″ means 3 feet – $3\frac{3}{8}$ inches.

All the drawings should be made on sheets of paper of half imperial size, viz: 22″ × 15″. The materials required are, Drawing board 23″ × 16″, T square with blade 24″ long, set square with one angle 60°, set square with two angles 45° (a useful size of set squares is 6″ on the shortest side). A case of mathematical instruments is also required containing compasses capable of drawing circles from $\frac{1}{8}$″ to 9″ radius, a pair of dividers, drawing pen, protractor, boxwood scales, india rubber, drawing pins and H pencils.

EXERCISES.

1.—Draw a plain scale of $2\frac{3}{4}$″ to the foot, showing inches and half inches, and long enough to measure 3 feet. Construct a line 1′ – $3\frac{1}{4}$″ long.

2.—Draw a plain scale of $\frac{7}{8}$″ to the foot, showing inches, and long enough to measure 10 feet. Construct a line 4′ – $6\frac{1}{2}$″ long.

3.—Draw a plain scale of $\frac{1}{7}$ showing inches and half inches, and long enough to measure 5 feet. Construct a line 1′ – $9\frac{1}{2}$″ long.

4.—Construct comparative scales to each of the above and draw a line in each case ·585 metres long.

PLANE GEOMETRY.

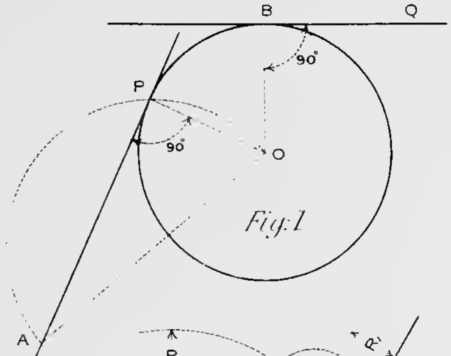
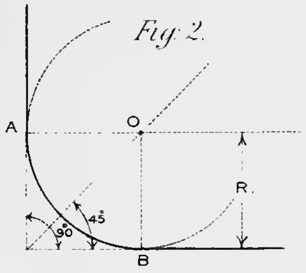


Fig: 1.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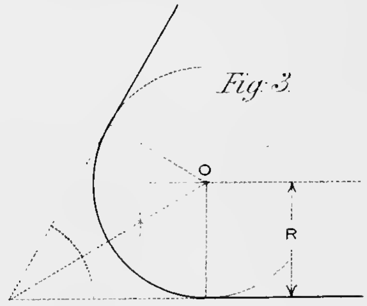
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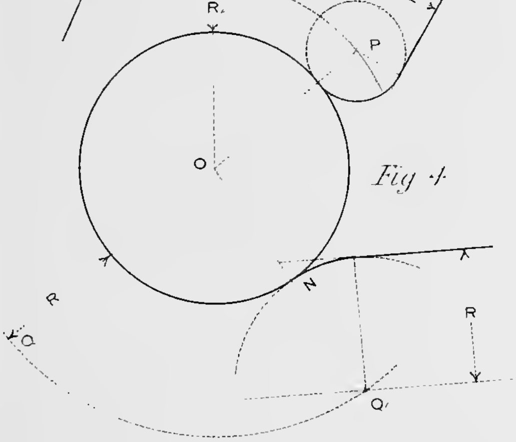
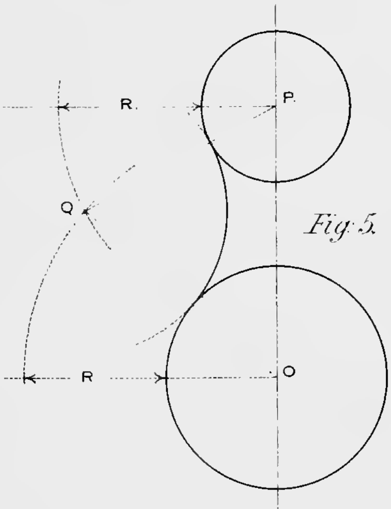


Fig: 4.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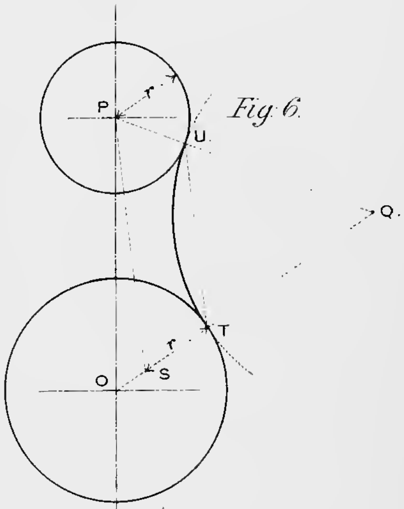
Fig: 6.

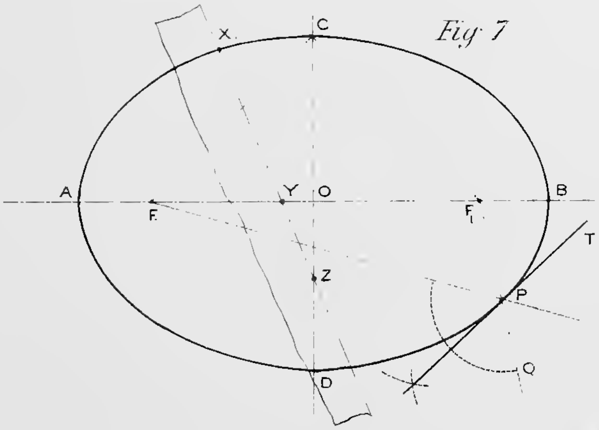
Fig: 7

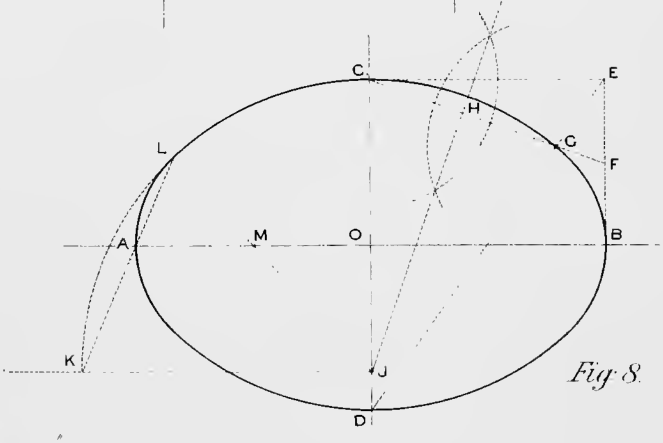
Fig: 8.

Scale 2" = 1 Foot.

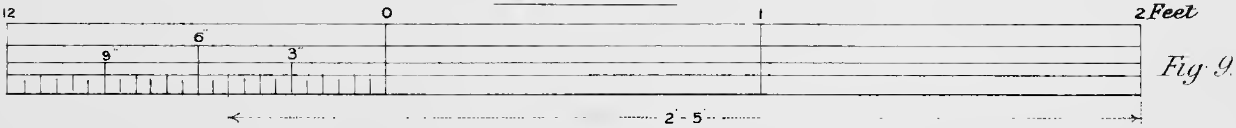
Fig: 9.

Scale 1/10 full size.

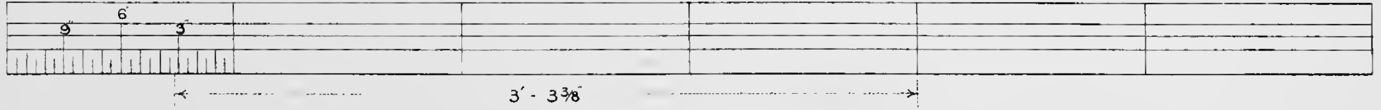
Fig: 10.

Comparative Metric Scale

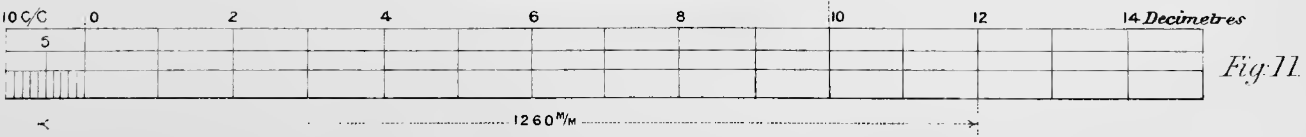
Fig: 11.

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Plate II.—PRINCIPLES OF PROJECTION.

THE chief purpose of a machine drawing is to enable the inventor or designer of a machine to convey his ideas to the workman, so that the machine can be constructed. It is necessary therefore for the drawing to give the exact form and size of the machine and its various parts. A perspective drawing shows at a glance, the general appearance of the machine or detail as viewed from one point, but the workman must have drawings which show the various details as they actually are and not as they appear; for this purpose, **orthographic projections** are used.

Orthographic projections are made by drawing lines, from every corner of the object, at right angles to the plane or surface upon which the projection or picture is made. Projections upon vertical planes are called **elevations,** and those upon horizontal planes, **plans.** Sections are also used, chiefly to show parts which are hollow. In the case of sections, the planes upon which the drawings are made pass through the solid. No solid can be fully represented by one projection; it is therefore necessary to make several, to give clearly and accurately its exact form and size.

In machine drawing, elevations are usually made upon vertical planes fixed at right angles or parallel to each other, **but in all cases the machine must be assumed to be placed between the plane upon which the elevation is drawn and the eye of the spectator.**

Fig. 1 shows three elevations and a plan of a square prism with small projecting prisms on three of its vertical faces.

Elevation A is projected upon the vertical plane No. 1, represented by X_1 Y_1 and shows the true form of the small triangular prism, and the face of the square prism upon which it is placed. It is the view as seen when looking in the direction of the arrow A.

Elevation B is projected upon the vertical plane represented by X_2 Y_2; the plane is then turned about its intersection with vertical plane No. 1 until it coincides with it. The elevation B is then drawn on the right hand side of the elevation A. This shows that the projecting prism on the left hand side as seen in the plan is a square one.

Elevation C is projected upon the vertical plane represented by X_3 Y_3, which is then turned round to coincide with vertical plane No. 1, and the elevation C is drawn on the left hand side of the elevation A. The projecting piece as shown on the right hand side of the plan is thus seen to be a cylinder. It should be noted that it is impossible to tell the shape of the projecting pieces on the right and left hand sides from the plan and elevation A alone.

Some draughtsmen would draw the elevation as seen in the direction of the arrow B in the position assigned to the elevation C in the drawing. It is clear that this could only be correct on the assumption that the prism is placed **behind** the vertical plane and not in **front** of it. As a rule all projections for industrial purposes are made on the understanding that the object projected is in the first pair of planes of projection, *i. e.,* **above** the ground, and in **front** of the vertical plane. Serious errors occasionally occur through this want of uniformity in projecting elevations.

Fig. 2 shows, in isometrical projection, the prism with its plan and two elevations; it will assist the student to understand the orthographic projections given in Fig. 1.

Figs. 3 and 4 show plan and elevation respectively of a hollow cube, and Fig. 5, a sectional elevation of it. Sectional elevations are always drawn upon vertical planes, parallel to the section plane, which must of necessity be a vertical one. The portion of the cube in front or farthest away from X Y, which is cut off by the section plane, is supposed to be removed, and the elevation of the remainder is then drawn. The **section** is thus always in front, and is the true shape of section, since it is on a plane parallel to the vertical plane of projection.

Fig. 6 shows a section of the cube as made by a plane inclined to the ground. The points in which this plane intersect the lines or edges of the cube, are the corners of the plane figure forming the section.

Suppose the cube to be solid, then the points 1 2 3 4 5 are the intersections of the section plane with the edges of the cube. The plans of these points must now be found by projection, and the **true form** of the section is then determined by drawing from each point in the elevation lines or projectors at right angles to the section plane. The distance from the section plane to point 1 in the section is equal to the distance of the *plan* of point 1 from X Y, and the other points are found in a like manner. Similarly the figure cut out of the section by hollowing the cube may be determined. In the method for finding sections described above it is assumed that the section plane is hinged to the vertical plane, and that it is turned round upon this hinge, bringing the section with it until it coincides with the vertical plane, upon which the section is then drawn.

Fig. 7 shows plan and two elevations of a solid cube. The left hand elevation is first drawn by copying the elevation Fig. 4, but with the base inclined to the horizontal plane; the plan is next drawn by projecting from the elevation and from the plan Fig. 3; **note that the point A is on the top and is the one seen in plan inside the bounding lines.** The second elevation is now found by projecting from the first one, and by projecting from the plan upon a vertical plane, and then turning the latter plane round into the original vertical plane; **note that the point E is now in front and is the one seen in this elevation inside its bounding lines.** Edges which cannot be seen are always shown in dotted lines.

EXERCISES.

Draw the various figures given on this plate, except Fig. 2, taking in each case larger solids and changing all the positions. A cube of 2½″ edge and a square prism 2″ × 2″ × 3¼″ will be convenient sizes.

PLATE II.

PRINCIPLES OF PROJECTION.

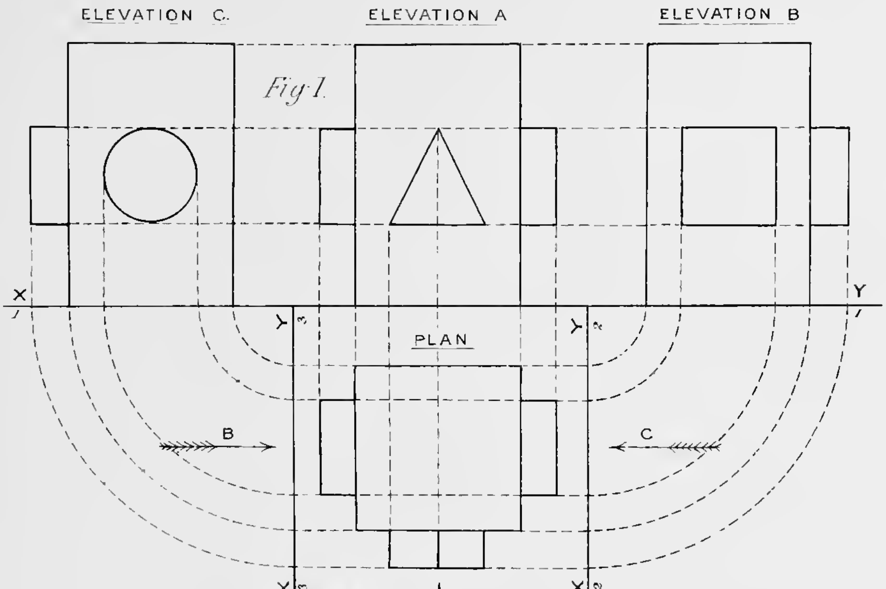
Fig 1.

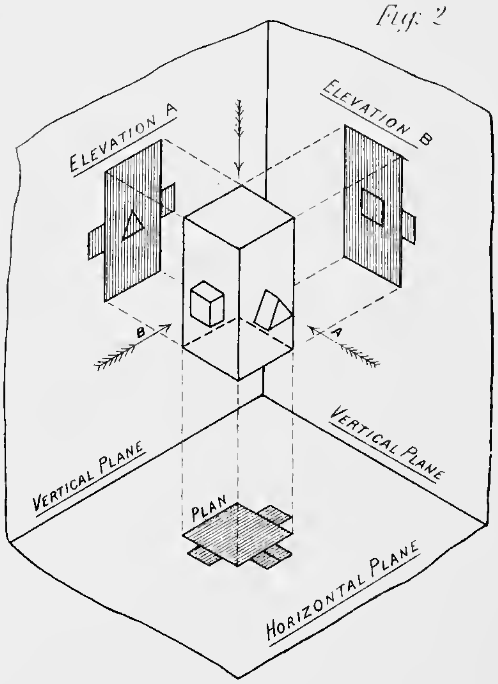
Fig: 2

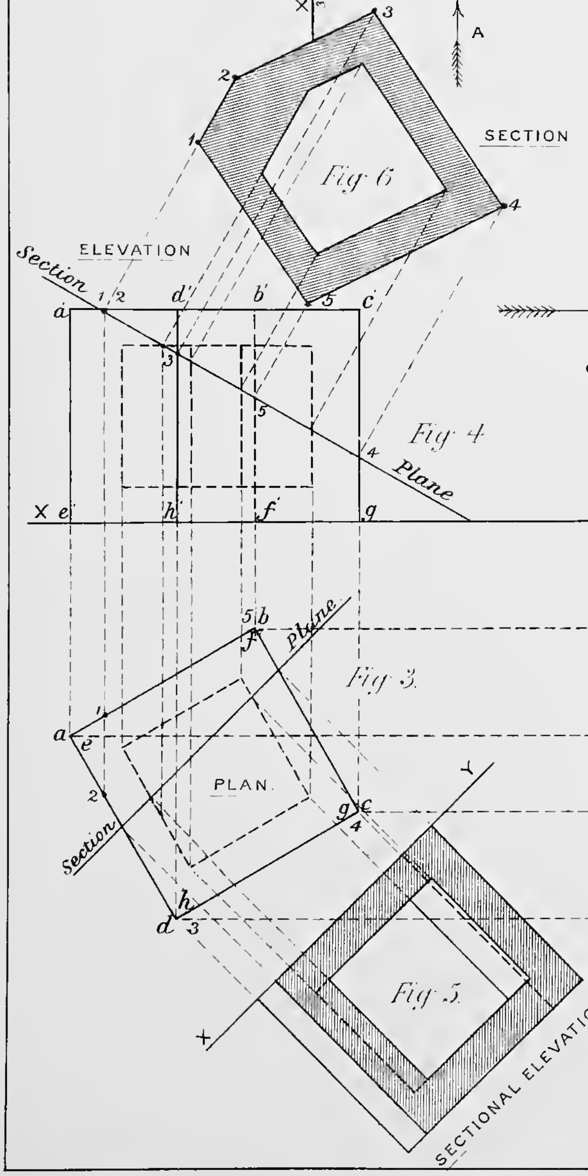
Fig 3. Fig 4. Fig 5. Fig 6.

PROJECTIONS OF A CUBE.

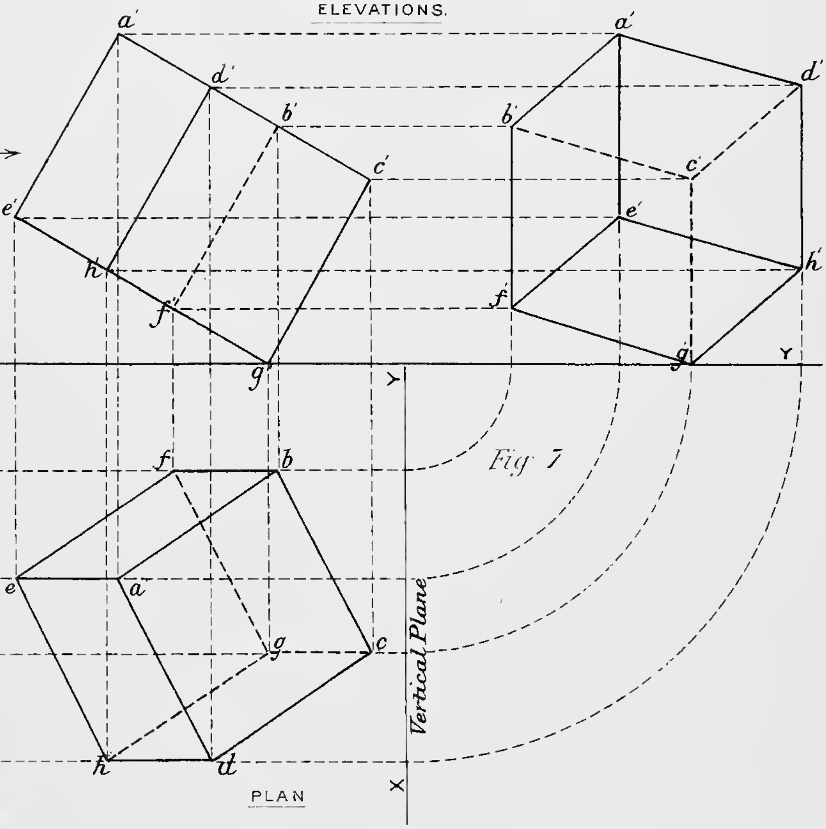
Fig 7

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Plate III.—INTERSECTIONS OF SURFACES OF SOLIDS.

THE projections of the lines, in which plane and curved surfaces intersect, is a branch of advanced geometry. The study of plane and solid geometry should be pursued simultaneously with that of Machine Drawing. The student must remember that he can never become an accomplished, or even a competent draughtsman, if he has no acquaintance with geometry. Geometry can give no knowledge of the construction or use of a machine, but it gives the power to correctly represent such machine on paper.

The intersections drawn on this plate, are those which often occur in machine drawing; the study of them may, however, be left for a time, until some power has been acquired of drawing simple examples of machine details.

The method of determining points in the intersection of the surfaces of solids, may be briefly stated thus:—A surface A, plane or curved, intersects a plane or curved surface B. Take a plane intersecting A in the line M, and suppose the **same** plane intersects B in the line N; then the point P, where M and N intersect, must be one of the required points, because it is on **both** the surfaces A and B. Some amount of skill is required to select planes, which will give the simplest sections of each solid.

Figs. 1 and 2. A is a cylinder, and B another one of the same diameter. B mitres into A at an angle of 45°, in the elevation given; the lines of intersection are really portions of ellipses, of which the lines shown are profile elevations. C is a cylinder of a smaller diameter than A. The method of finding the extreme point of intersection *a, a'* is clearly shown. To find any other point as *b, b'*, assume a vertical plane parallel to the axes, intersecting A in a vertical line passing through *b* and intersecting C in lines parallel to its axis. The lines intersect each other in the points *b, b'*; the heights of these points above and below the axis of C, are shown by the semi-circle.

Figs. 3 and 4. E is a square prism, intersecting the truncated cone D; planes parallel to the ground, passing through 1-2-3-4-5, are taken. The sections of the cone are circles of varying diameters, and those of the prism, rectangles. The plans of the circles are first drawn, and where these intersect the parallel lines, as shown in the plan, are points in the required line. See the point *b, b'* as an example. F is a cylinder also intersecting D. The same horizontal section planes are used as in the previous example, giving the **same** circles as sections of the cone. The sections of the cylinder are rectangles of varying widths. The method of finding the points *a, a'* is shown. The distance *m' a'* determined in the semicircle, is half the width of the section of the cylinder, made by the plane passing through the point 2.

Figs. 5 and 6 show the intersection of a solid of rectangular section, with a cylinder. A hollow corner is made at the junction of the two solids. Horizontal sections are taken through the points 1-2-3. The sections of the cylinder, are circles of varying diameters; these are drawn in the plan, by projecting their radii from the elevations. The intersections of these circles, with the vertical faces of the rectangular solid, give the plans *a, b, c, d,* of points, in the curve of intersection. The elevations are then found by projection. **Note.—This example will be found useful in the drawing of cranks.**—See Plate XIX.

Figs. 7 and 8 show the method of finding the intersection of the round part of a connecting rod end, with the flat portion carrying the steps, &c.—See Plate XXIII.

Horizontal sections are taken through 1-2-3-4 as in the previous example. To find the extreme points *a, a'* the circle is first drawn in the plan, having its diameter equal to the thickness of the flat end. This projected to the elevation, gives the position of the horizontal plane through the point 1, containing the point *a' a.* The remaining points *b, b', c, c'* and *d, d'* are found as previously explained.

EXERCISES.

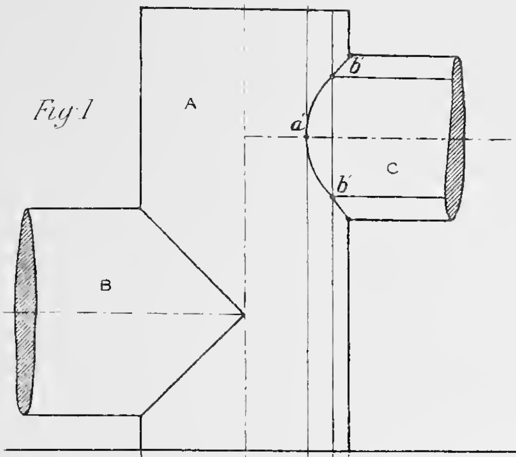
Draw these intersections of surfaces, using different dimensions in all cases so as to avoid the temptation to copy.

PLATE III.

INTERSECTIONS OF SURFACES OF SOLIDS.

FRONT ELEVATION

Fig 1



FRONT ELEVATION

Fig 3.

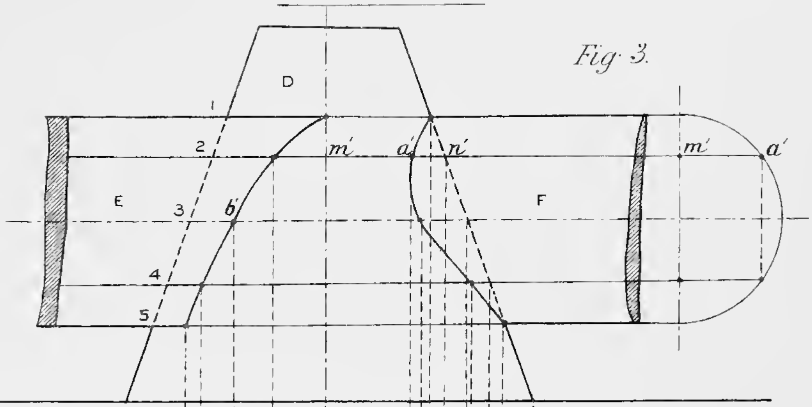
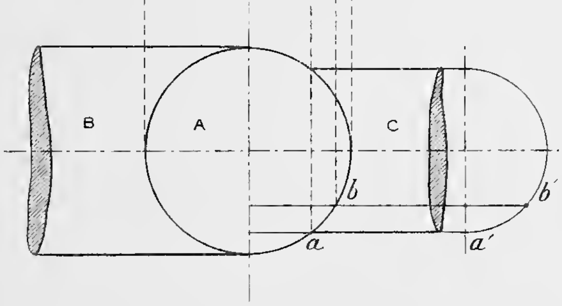


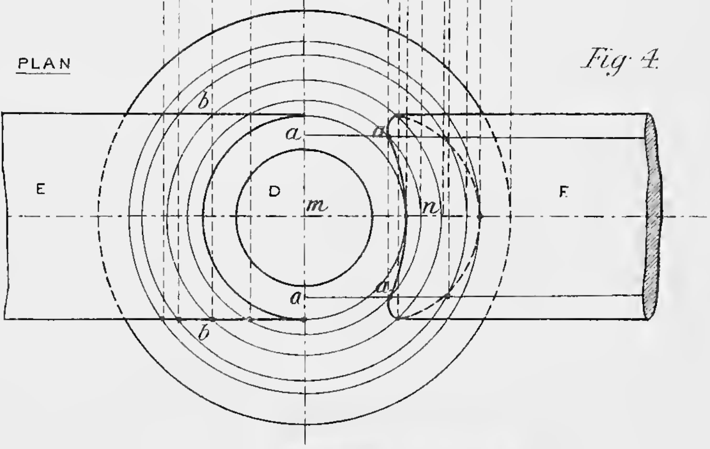
Fig 2.

PLAN.



PLAN

Fig 4.



FRONT ELEVATIONS.

Fig 5.

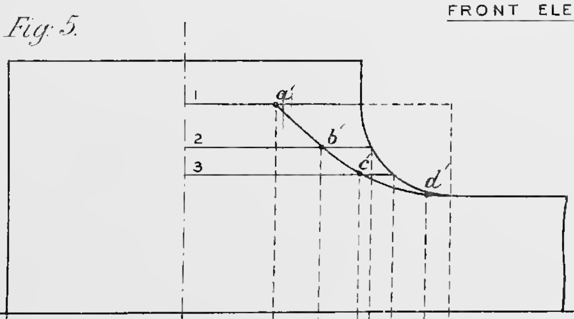


Fig 7.

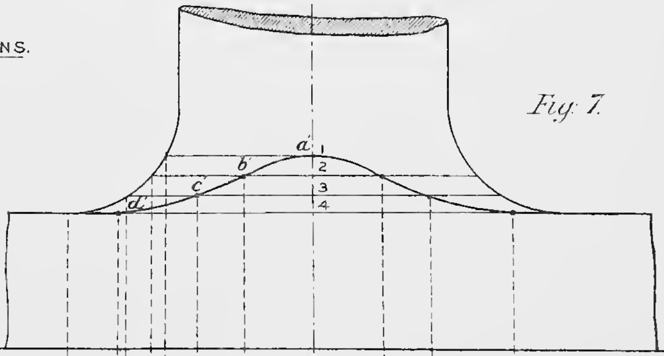
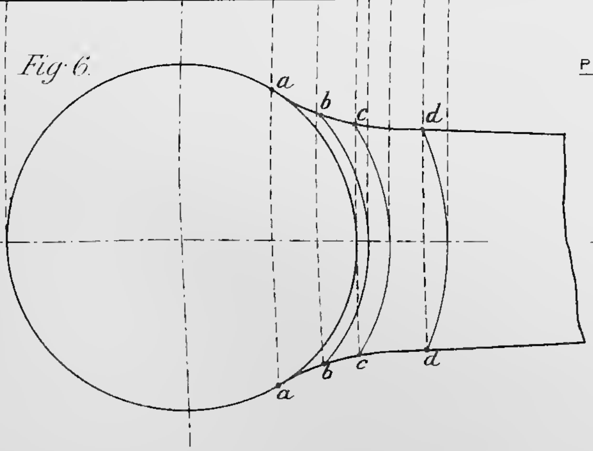
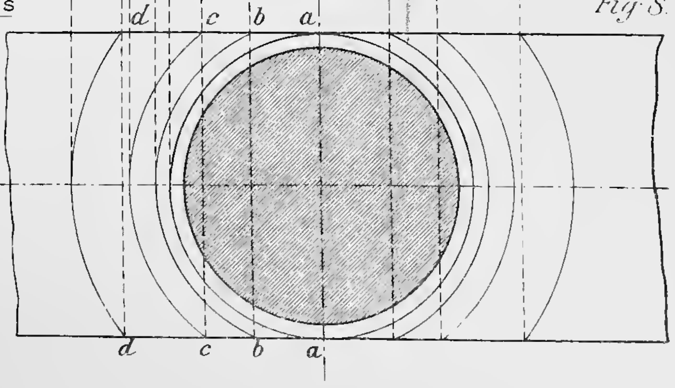


Fig 6.



PLANS

Fig 8.



T. JONES.
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Plate IV.—RIVETS AND RIVETED JOINTS.

RIVETS are used to connect metal plates permanently together, as required in the construction of wrought-iron or steel boilers, bridges, roofs, &c. They are cylindrical in form, and are forged with a head at one end, the other one being made by a machine, or by hand, when the rivet, which is made red-hot, is placed in position through the plates. The heads, as shown in the drawings, are of various forms, their dimensions bearing a fixed proportion to the diameter of the body, which is here represented by the number 10.

Fig. 2 is a scale for obtaining the dimensions of the heads for a rivet of any given diameter, the vertical lines being the radii, and the horizontal lines the heights.

In designing a boiler the thickness of the plates to resist the required steam pressure must first be determined. The diameter of the rivet is then proportioned to this thickness. Prof. Unwin gives the formula, $\mathbf{d} = 1{\cdot}2\sqrt{\mathbf{t}}$, where **t** is the thickness of the plate, and **d** the diameter of the rivet suitable for this thickness.

Fig. 1 shows a graphic method of finding **d** when **t** is given; $1{\cdot}2\sqrt{\mathbf{t}} = \sqrt{1{\cdot}44\ \mathbf{t}}$. The latter expression is used, since it admits of a neater and simpler construction. A B, the diameter of the semi-circle, = 1·44″, $\mathrm{A\ C} = \frac{1}{2}'' = \mathbf{t}$, then A D = diameter of the rivet for a plate ½″ thick; since $\mathrm{A\ D} = \sqrt{\mathrm{AB} \times \mathrm{AC}} = \sqrt{1{\cdot}44 \times \frac{1}{2}}$, and so on for any other value of **t.**

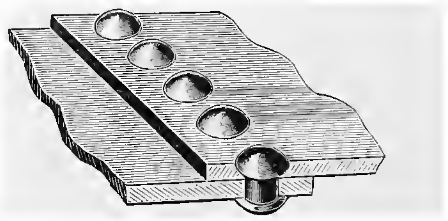
The next step is to determine the proper **pitch** or distance between the centres of the rivets. Referring to the single-riveted joint, Fig 5, it will be seen that the pitch is equal to the diameter of the rivet + the distance between two consecutive holes. The force on the joint due to the steam pressure, tends to rupture it; and if the pressure were sufficiently great the joint would give way, either by tearing the plates asunder or by shearing the rivets. If we take the resistance to shearing and tearing to be equal, then the area of the section of the plate between the rivet holes should be equal to the area of the rivet. Let t = thickness of plate in inches, d = diameter of rivet in inches, P = pitch of rivets in inches, then—

$$t\,(\mathrm{P} - d) = d^2\,\tfrac{\pi}{4} \quad \left[= d \times d\,\tfrac{\pi}{4} = d \times \tfrac{11}{14}\,d\right].$$

$$\therefore\ \mathrm{P} - d = \frac{d^2\,\frac{\pi}{4}}{\mathrm{t}} = \frac{\text{area of rivet.}}{\mathrm{t}}$$

Fig. 4 shows a graphic method of determining P when *t* & *d* are given. $t\,(\mathrm{P} - d) = d \times \frac{11}{14}\,d\ \therefore\ t : d :: \frac{11}{14}\,d : \mathrm{P} - d.$

Draw the right angled triangle O M N, making O M = 14, and MN = 11 to any scale; make O R = *d*, and R S at right angles to it = *t*, and produce S R to T, and draw the line T V parallel to O M. Join S O and produce to U, then U W = P − d and U T = P, the required pitch. To make this clear, it is only necessary to note that $\mathrm{O\ W} = \mathrm{R\ T} = \frac{11}{14}$ d. On referring to the double-riveted joint (Fig. 6) it will be seen that there are two rivets to the pitch; therefore the section of plate between two consecutive holes, must be double the area of that in a single-riveted joint. The pitch P_1 for a double-riveted joint is found by adding P − d to P. In Fig 3 a series of pitches is determined for various sizes of plates, drawn in connection with Figs. 1 and 2. Letters of reference are given in the diagrams for the various proportions for a riveted joint of ½″ plates. $\mathrm{A\ C} = \frac{1}{2}'' = t$; $\mathrm{O\ P} = \mathrm{V\ S} = \mathrm{A\ D} = d$; $\mathrm{P\ Q} = t$; then $\mathrm{S\ T} = \mathrm{P}$ and $\mathrm{SY} = \mathrm{P}_1$. The proportions for the rivet heads are distinctly marked in Fig. 2.



Figs. 5 and 6 show lap joints, the plates being made to overlap each other. In Fig. 5 the overlap of the plates = 3 *d*, and in Fig. 6 = 5 *d*. In the latter case the pitch measured diagonally should not be less than P.

Fig. 7 shows a butt joint; the two plates meeting or butting together, a narrow plate or strap being used to connect them. Sometimes two straps are used, one on each side of the plates. An example of each kind is given. A single-riveted joint is about 60 per cent. the strength of the solid plate, and a double-riveted one 75 per cent.

The Following Table will be found Useful.

Thickness of Plate. t	Diameter of Rivet. d	Thickness of Plate. t	Diameter of Rivet. d
$\frac{1}{4}''$	$\frac{9}{16}''$	$\frac{9}{16}''$	$\frac{7}{8}''$
$\frac{5}{16}$	$\frac{11}{16}$	$\frac{5}{8}$	$\frac{15}{16}$
$\frac{3}{8}$	$\frac{3}{4}$	$\frac{3}{4}$	$1\frac{1}{16}$
$\frac{7}{16}$	$\frac{13}{16}$	$\frac{7}{8}$	$1\frac{1}{8}$
$\frac{1}{2}$	$\frac{7}{8}$	1	$1\frac{3}{16}$

EXERCISES.

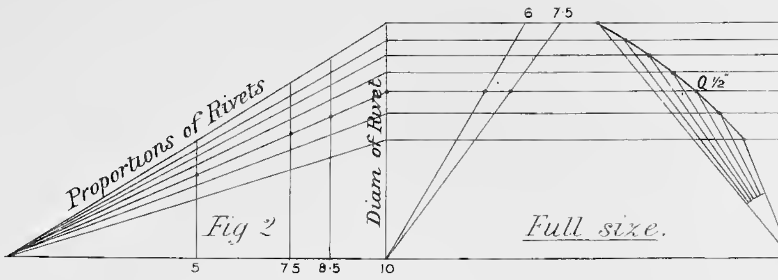
1. Draw an example of each of the rivet heads, taking $d = 1''$. **Note.—A scale must be drawn similar to Fig. 2.**
2. Draw each of the joints shown in Figs. 5, 6, and 7, *full size.*
3. Draw a double-riveted **butt** joint for ⅝″ plates, *full size.*
4. Design any or all of the joints given, but for ½″ plates, *full size.*

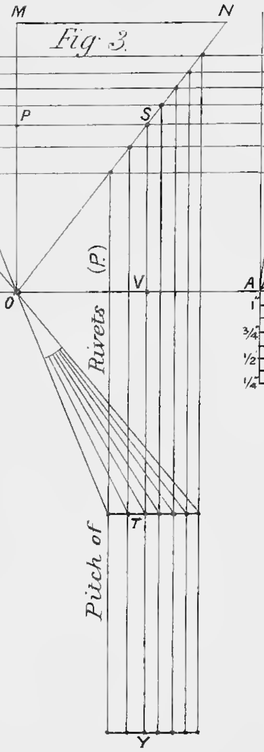
QUESTIONS.

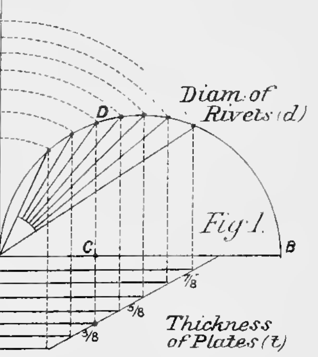
1. Show by sketches in how many ways a riveted joint may give way.
2. Describe in detail how a rivet is put into place and riveted.
3. Explain the method of **caulking** a riveted joint to make it steam tight.

RIVETS AND RIVETED JOINTS.

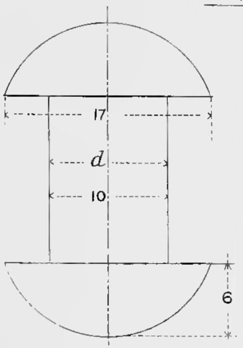
PLATE IV



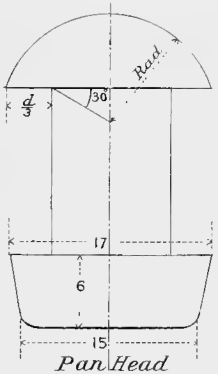




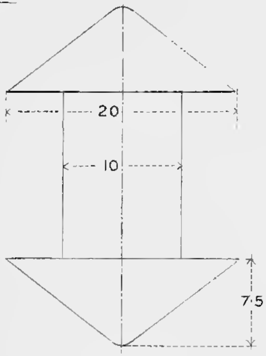
FORMS OF RIVET HEADS.



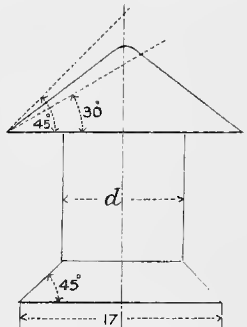
Cup Head



Pan Head



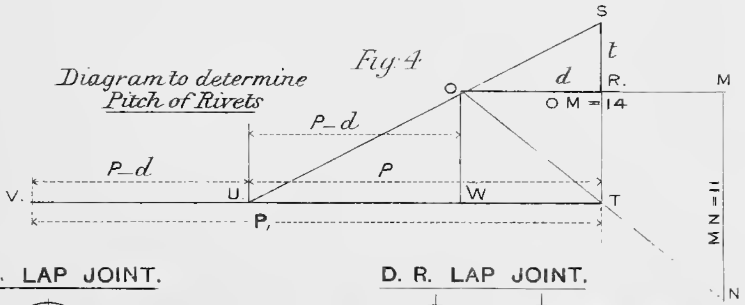
Conical Head

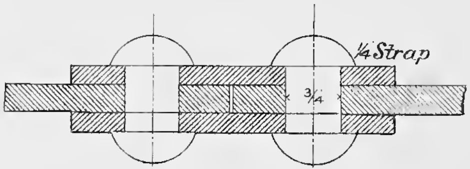


Countersunk Head

Diagram to determine Pitch of Rivets

Fig. 4





S. R. LAP JOINT.

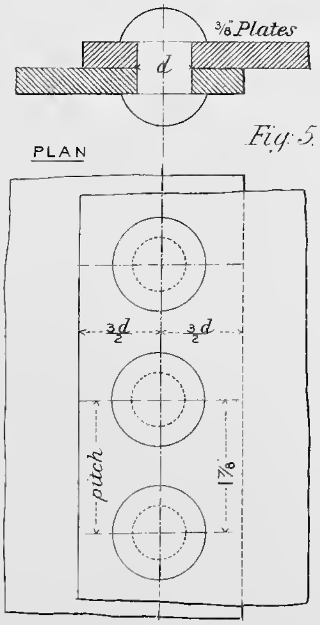


Fig. 5.

D. R. LAP JOINT.

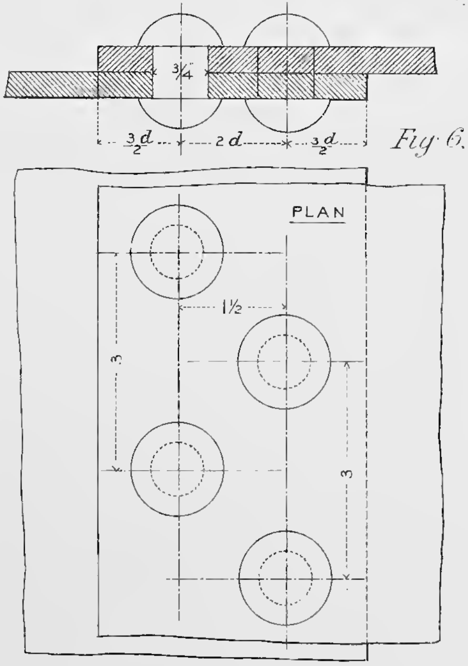


Fig. 6.

Scale ⅜ or 4½ = 1 Foot

S. R. BUTT JOINTS.

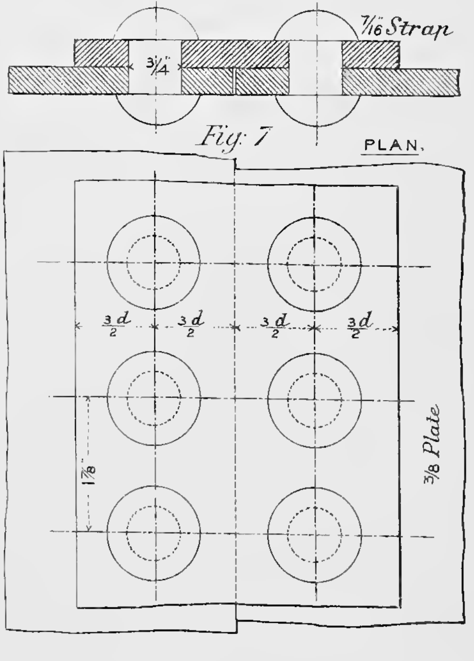


Fig. 7

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Plate V.—EXAMPLES OF RIVETED WORK.

IN riveted structures it is often necessary to connect plates together in ways differing from those shown in Plate IV. For instance, the plates may be parallel to each other but at some given distance apart, or they may be at right angles, or any other angle, to each other. The connections are effected by the use of bars of rolled iron of a section suitable to the required purpose.

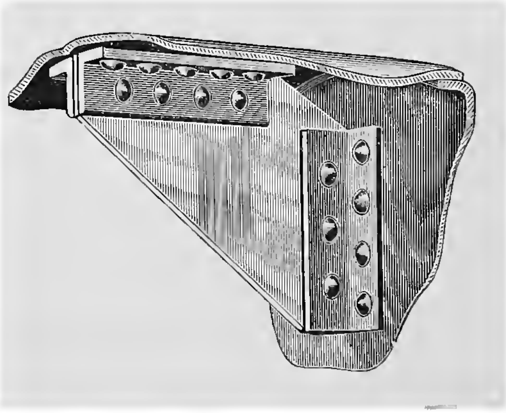
Examples of bars of various sections are shown. They are made in many sizes, the thickness of metal being proportioned to their dimensions; but in all cases the plates are a little thinner at the outer edges, tapering gradually from the angles.

Fig. 1 shows an angle iron used to connect two plates at right angles to each other. Each plate is secured to one face of the rolled bar by a single line of rivets. It may be here noted that the pitch of the rivets should be a little greater than that used in boiler work. By the use of angle irons and flat plates, girders of various forms and sizes may be built together.

Fig. 2 shows a butt joint, where the plates are connected by a piece of T iron instead of a flat strap. This serves the double purpose of holding the plates together and stiffening them at the same time.

Fig. 3. Two parallel plates are here shown connected by a channel iron. This illustrates one of the methods used to connect the inner and outer fire box of a locomotive.

The Gusset Stay, shown in the drawing and in the accompanying illustration, is used to strengthen the weakest part—that is, the flat end of a boiler shell. The stay is a single plate of wrought-iron or steel, and is attached to the flat end and cylindrical surface respectively, by means of angle irons. All vessels subjected to internal pressure tend to become spherical, and the flat ends of a boiler would bulge outwards if they were not stayed.



Mud hole cover.—In a Lancashire boiler the mud hole is placed at the bottom of the front end, between the furnaces. In washing and cleaning out the boiler, the whole of the sediment is discharged through the mud hole. In the example given, a cast iron elliptical frame is riveted to the inside of the front plate; the cover, which is also of cast iron, being held in position by two wrought iron cross bars fitting into recesses in the frame, each secured by a bolt passing through the centre. The stress upon the bolts is that due to screwing up alone, the steam pressure within the boiler tending to keep the cover in its position on the face of the frame. The thin plate in the front, held by the central stud bolt, is used to cover up the opening in the frame.

EXERCISES.

1.—Draw the rolled iron sections to the given dimensions, the L and T sections *full size*, and the U and H sections *half size.*

2.—Draw the angle iron joint Fig. 1 *full size*, adding a plan projected from the front elevation.

3.—Draw the two joints shown in Figs. 2 and 3, adding a plan in each case. *Scale* $\frac{3}{4}$ *full size.*

4.—Draw the two views of the mud hole cover as given, and add a section by a horizontal plane passing through the major axis of the ellipse. The latter view should be projected and shown as a sectional plan. *Scale 6″ = 1 foot.*

5.—Draw the two views of the Gusset stay, as shown. *Scale* $\frac{3}{8}$ *full size.*

Note.—In all the above examples, the cup-heads of the rivets may be drawn by the approximate method shown on Plate IV.

EXAMPLES OF RIVETED WORK.

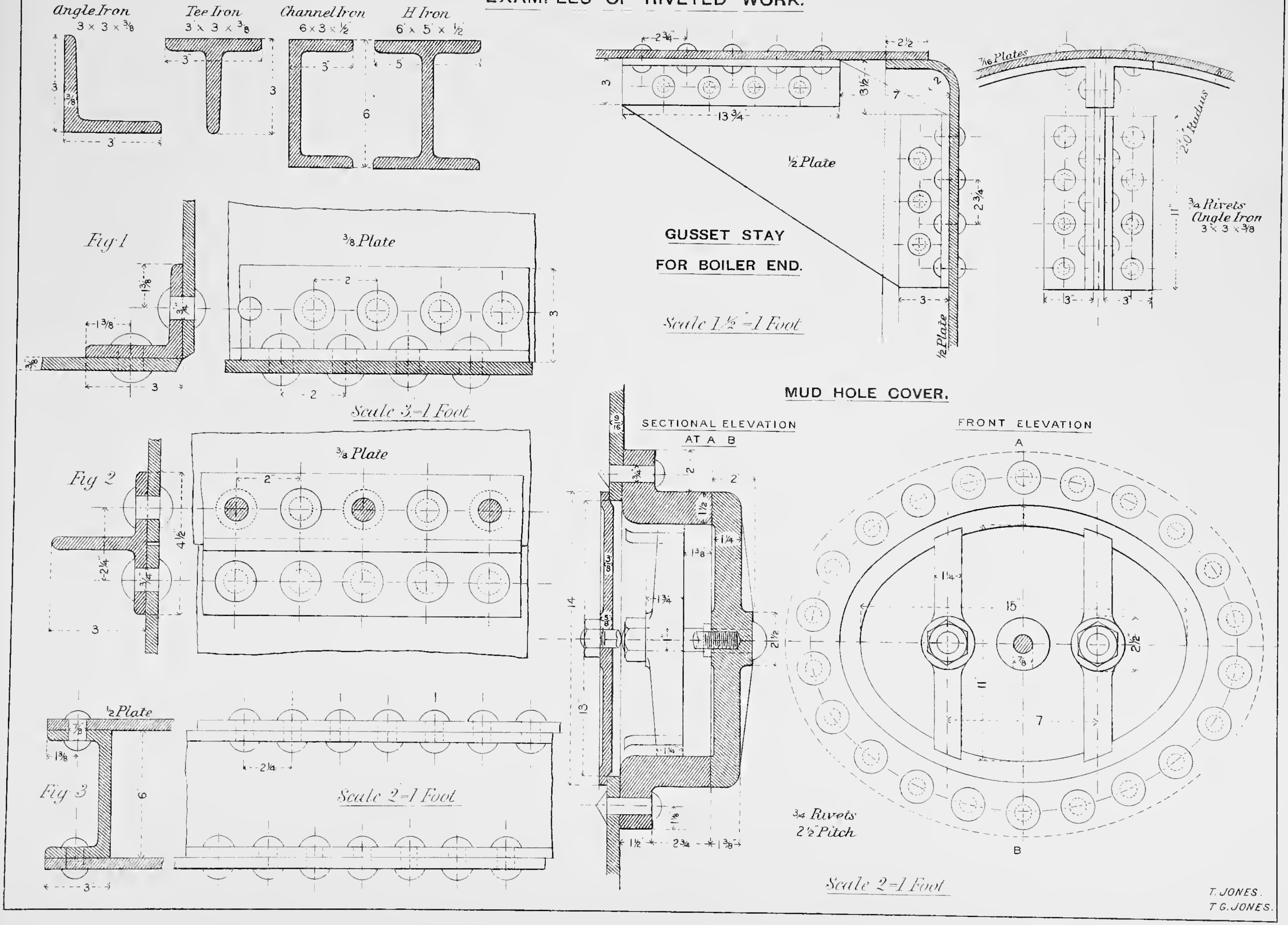


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Plate VI.—PROJECTIONS AND FORMS OF SCREW THREADS.

A CYLINDRICAL helix is a line of double curvature, that is, it cannot lie on a plane surface, although it becomes a straight line when the surface upon which it is traced is laid flat or developed. To trace this curve, suppose a point to travel upon a cylindrical surface, placed with its axis vertical, in such a manner that it moves at a constant angular velocity and also at a constant vertical velocity; the point will trace a helix.

Again, if we assume one end of a line to travel along this curve, and to be at right angles to the axis of the cylinder in all positions, it will generate a helical surface, which is the one generated by the tool in a screw cutting lathe. This is seen the best in a square threaded screw. The slide rest in moving to give the feed, causes the corners of the cutting tool to generate two straight lines at right angles to the axis of the cylinder, upon which the thread is being cut; these lines are carried along by the threads on the guide screw, uniformly with the revolutions of the lathe spindle.

One line generates the helical surface on the right hand side of the thread, and the other line that on the left hand side, the space being cut out by the face of the tool. The *pitch* of a screw is the distance it will move in the direction of its axis in one revolution through a fixed nut.

Fig. 1 shows the method of drawing the curve. A semicircle is drawn in plan, and the arc divided into a number of equal parts 1-2-3-4, the divisions for the other half, 5-6-7-8, being shown on the same semicircle. The pitch, from 0 to 8, in the elevation, is also divided into eight equal parts. The drawing shows clearly how the elevations of the points are obtained by projection. One and a half revolutions are shown.

Fig. 2 shows a cylindrical piece coiled into the form of a screw thread. The centre line or axis must be projected in the same way as Fig. 1, and a series of circles, equal to the diameter of the cylinder, described in the elevation from the points 1-2-3, &c., as centres. Curves drawn tangential to these circles will give the elevation of the solid.

Fig. 3. In this example a piece of square section is projected. There are two distinct proportions of helices, one described upon the smaller cylinder and the other on the larger one.

The best way to draw this example is to assume a series of vertical planes passing through the axis of the generating cylinders and cutting the solid; the sections which are all squares have their elevations a series of rectangles. When these elevations are found, the curves which pass through the corners of the rectangles can easily be drawn. The points are shown for one-half revolution.

Fig. 4 shows sections of the various screw threads in common use. In the **Whitworth,** introduced by Sir Joseph Whitworth, the angle between the threads is 55°, the top and bottom of the thread being rounded off $\frac{1}{6}$ of the depth, leaving the working depth $\frac{2}{3}\,d$. The distance between the centres of two consecutive threads, in a single threaded screw is the pitch.

In the **Sellers'** thread, introduced by Mr. Sellers, of Philadelphia, the angle is 60°, the depth being reduced $\frac{1}{8}\,d$ at the top and bottom as shown, leaving the working depth $\frac{3}{4}\,d$. Both these forms of thread are very strong to resist shearing, but the friction is very great, and the force exerted upon the thread reacting at an angle with the axis of the screw, tends to burst the nut.

In the **square** thread, the forces react in a direction parallel to the axis, and this form is used for transmitting great pressures, and is almost universally adopted for screw presses, slide rests for lathes, table and cross slides of planing machines, &c. A square thread has only half the shearing area as a V thread of the same pitch. The **buttress** thread, which combines these two forms, is used to transmit a force in one direction only. The **knuckle** thread is used when a split nut is required for disengaging from the screw at any part of its length, as in the case of the traversing screw of a shaft turning lathe.

Fig 5 shows a V thread and a single and double square thread, with the helical curve correctly drawn.

In the double threaded screw there are two threads to the pitch. These are all *right hand* screws, the curves rising to the right hand side in the front, and to the left hand side as they wind round the back. If nuts to fit these screws were cut across the centre, and looked at towards the sectioned surface, the threads would appear left handed, since they fit against the backs of the screws.

Fig 6 shows approximate methods of representing screws in drawings. *The slope of the threads should be half the pitch.*

Fig. 7. In this diagram the vertical lines drawn to scale show the numbers of threads per inch for the various diameters of bolts, measured on the horizontal scale. These are taken from Whitworth's standard as given in the table below.

WHITWORTH SCREWS.

Diam. of Screw. 1	Number of Threads per in. 2	1	2	1	2	1	2
$\frac{3}{16}''$	24	$\frac{7}{8}''$	9	$1\frac{7}{8}''$	$4\frac{1}{2}$	$3\frac{3}{4}''$	3
$\frac{1}{4}$	20	1	8	2	$4\frac{1}{2}$	4	3
$\frac{5}{16}$	18	$1\frac{1}{8}$	7	$2\frac{1}{4}$	4	$4\frac{1}{4}$	$2\frac{7}{8}$
$\frac{3}{8}$	16	$1\frac{1}{4}$	7	$2\frac{1}{2}$	4	$4\frac{1}{2}$	$2\frac{7}{8}$
$\frac{7}{16}$	14	$1\frac{3}{8}$	6	$2\frac{3}{4}$	$3\frac{1}{2}$	$4\frac{3}{4}$	$2\frac{3}{4}$
$\frac{1}{2}$	12	$1\frac{1}{2}$	6	3	$3\frac{1}{2}$	5	$2\frac{3}{4}$
$\frac{5}{8}$	11	$1\frac{5}{8}$	5	$3\frac{1}{4}$	$3\frac{1}{4}$	$5\frac{1}{2}$	$2\frac{5}{8}$
$\frac{3}{4}$	10	$1\frac{3}{4}$	5	$3\frac{1}{2}$	$3\frac{1}{4}$	6.	$2\frac{1}{2}$

EXERCISES.

1.—Draw Fig. 1; diameter of cylinder, $2\frac{1}{2}''$, pitch 1″. Fig. 2; mean diam. 3″, pitch 2″, and diameter of section $\frac{3}{4}''$. Fig. 3; outside diameter, 4″, pitch $1\frac{1}{2}''$, section, a square of $\frac{5}{8}''$ side.

2.—Draw the various sections of screw threads given in Fig. 4. Pitch in each case to be 1″.

PROJECTIONS AND FORMS OF SCREW THREADS.

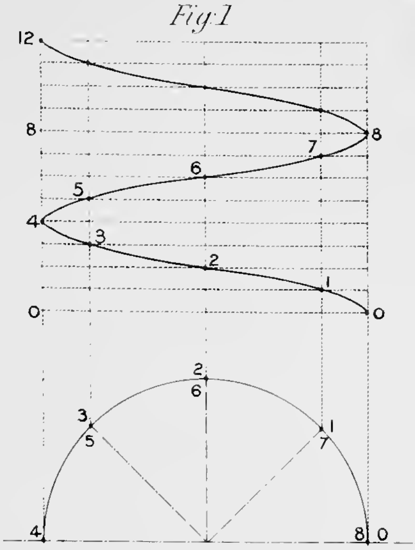
Fig 1

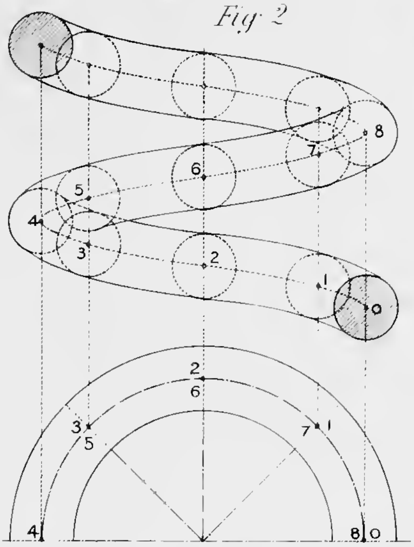
Fig 2

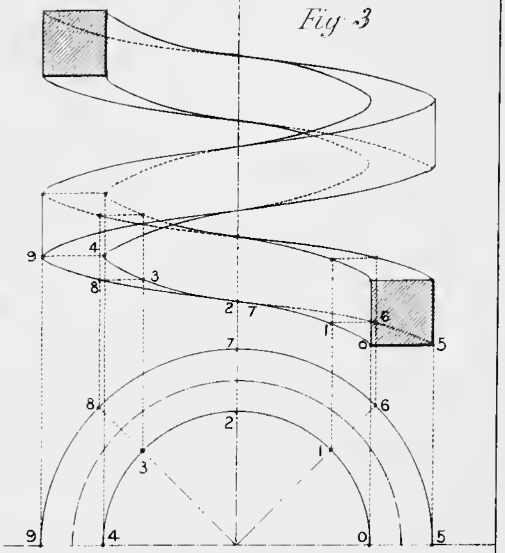
Fig 3

SECTIONS OF SCREW THREADS.

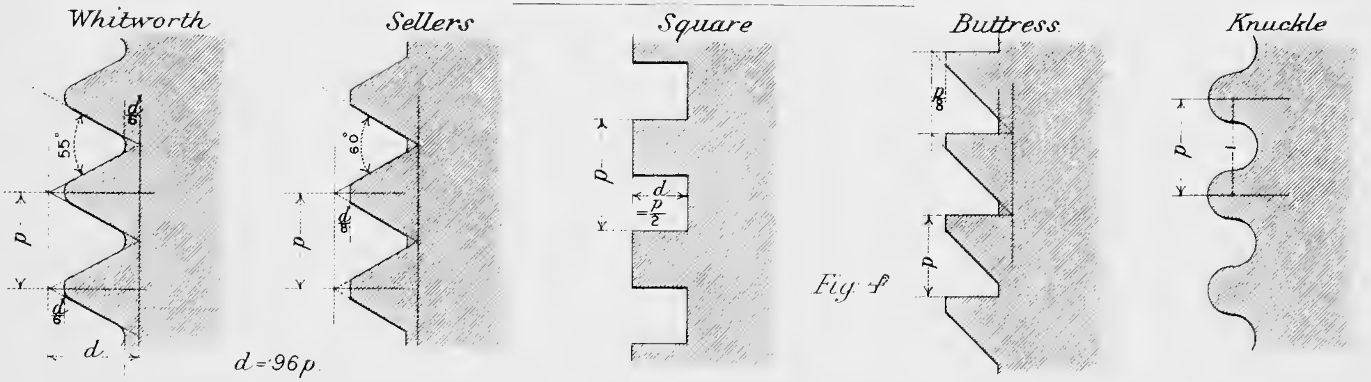
Whitworth Sellers Square Buttress Knuckle

Fig 4

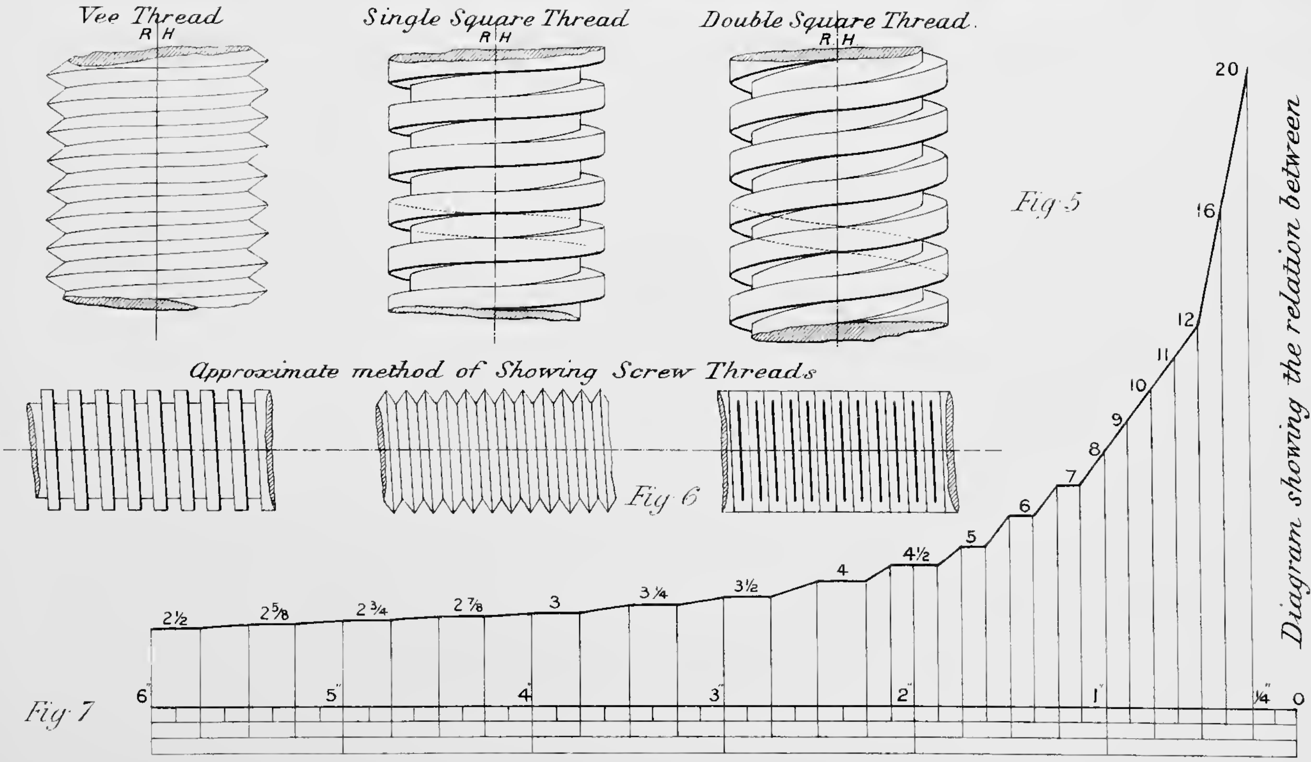
Vee Thread Single Square Thread Double Square Thread

Fig 5

Approximate method of Showing Screw Threads

Fig 6

Fig 7

Diagram showing the relation between the number of threads per inch, and diameter of Screw

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Plate VII.—NUTS AND BOLTS.

BOLTS and nuts are used as temporary fastenings for the various parts of machines. They hold the parts firmly together, but can be easily disconnected when required. The body of the bolt is cylindrical, a head, of which there are many forms, is forged on one end; at the other end a screw thread is cut, upon which the nut moves. The nut forms what is practically another head, which is adjustable to the parts, and capable of drawing them tightly together.

Fig. 3. Three forms of bolt heads are given; in each case a method is shown of preventing the rotation of the bolt when the nut is being screwed up. The most common form is that shown in Fig. 5. Hexagonal heads are also used, chiefly in good work, when they are visible.

Nuts are generally made of the form of square or hexagonal prisms, so that they may be turned round on the bolt by means of a screw key fitting on any two parallel faces. The hexagonal nut is preferred to the square one for several reasons: It is stronger for the same amount of metal, has a nicer appearance, and is easier to tighten up when in a contracted space.

The distance between the parallel faces of a nut is proportional to the diameter of the bolt.

The following formula is approximately correct for Whitworth's standard nut: $\mathrm{D} = 1\frac{1}{2}\, d + \frac{1}{8}''$ where D = diameter across the flats or faces; d = diameter of bolt.

Fig. 1 is a scale for various sizes of nuts to this proportion. For example, $a\,b$ = radius of bolt, $a\,c = \frac{\mathrm{D}}{2}$ or radius of inscribed circle of hexagon, and $a\,d$ = half the distance across the angles.

The usual depth or thickness of a nut $= d$, but in special cases a *deep* nut is used, the depth being $1\frac{1}{2}\, d$.

The nut is always chamfered at the top, and sometimes at the bottom. The curves formed on the *flats* of the nuts are hyberbolas, since they are sections parallel to the axis of a conical surface.

In representing a nut to a small scale on a drawing, the proportions given in **Fig. 2** are sufficiently accurate.

When the chamfer is at an angle of 45°, the curves on the *flats* coincide very nearly with the arc of a circle of radius *d*. The radii for the projections of these arcs in the other positions are given.

In these proportions, the width over the angles of the nut $= 2\ \mathrm{d}$; the width over faces or *flats* $= 1\frac{3}{4}\ \mathrm{d}$. If these proportions be remembered, each view can be drawn independently of the others. The best way to draw the hexagonal projection is to first draw a circle of diameter *d*, then another, concentric with it of diameter $1\frac{3}{4}\ \mathrm{d}$. The hexagon can be drawn by making tangents to the circle with the T square and 60° set square.

When bolts and nuts are used to connect parts together which are subjected to continual vibration, the nuts are liable to work loose. To prevent this various methods of locking them have been adopted.

In **Fig. 6**, a second nut, called a *lock nut*, of thickness $\frac{d}{2}$, is usually placed on the top of the ordinary nut.

In **Fig. 7** the lower portion of the nut is cylindrical, and has a groove turned in it, into which the end of a set screw fits.

Fig. 8. The locking is here effected by tightening the small set screw, and so binding the nut against the thread on the bolt.

Fig. 9. A split pin passed through the bolt prevents the unscrewing of the nut.

Fig. 10 represents a **stud bolt.** One end is screwed into one of the parts; it retains its position when the nut is removed. Sometimes the plain portion of the stud is made square, so that it can be screwed into position with the screw key.

EXERCISES.

1.—Draw an ordinary $1\frac{1}{4}''$ nut, chamfered on both sides. *Scale full size.*

2.—Draw, by means of Fig. 1, the various views for a standard nut for $1\frac{1}{2}''$ bolt. *Full size.*

3.—Draw *full size*, the bolt and nut as given in Fig. 5, adding a plan. *Note. Washers may be made* $\frac{1}{7}\, d$ *thick and* $2\frac{1}{4}\, d$ *diameter.*

4.—Draw *full size*, adding a plan in each case, Figs. 7 to 10 inclusive.

5.—Draw a set screw $\frac{3}{4}''$ diameter, $3\frac{1}{2}''$ long, with hexagonal head. *Scale* $\frac{3}{4}$ *full size.* See Fig. 4.

PLATE VII

NUTS AND BOLTS.

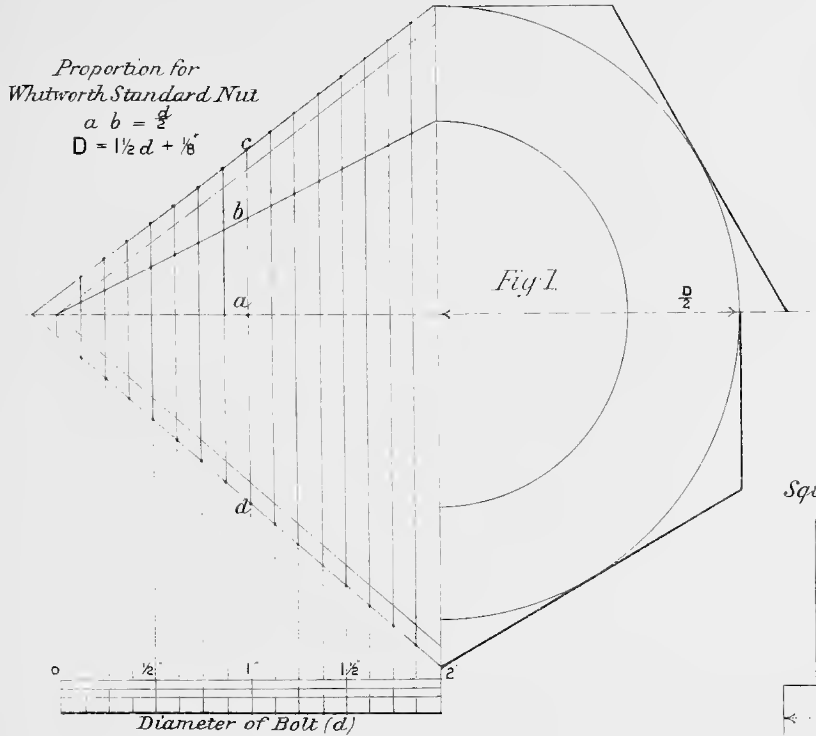
Proportion for Whitworth Standard Nut
$a\ b = \frac{d}{2}$
$D = 1\frac{1}{2}d + \frac{1}{8}''$

Fig 1.

Approximate proportion for Hexagonal nut

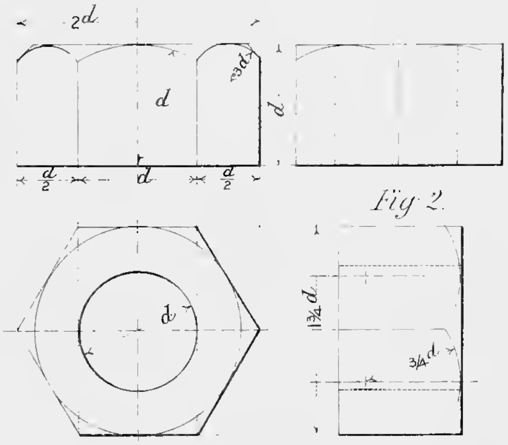
Fig 2.

FORMS OF BOLT HEADS.

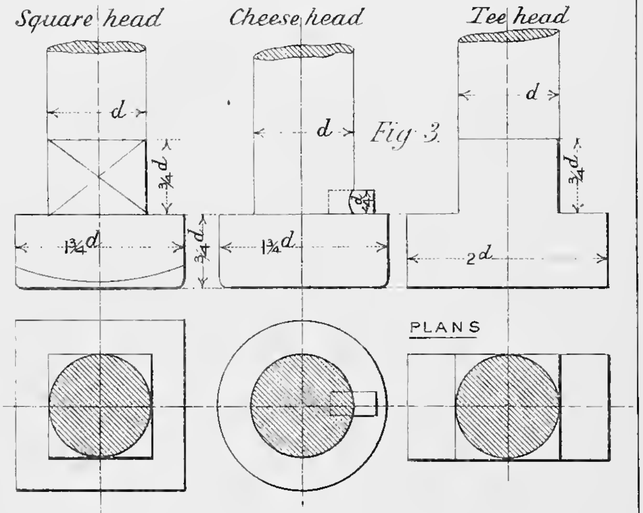
Fig 3.

SET SCREW.

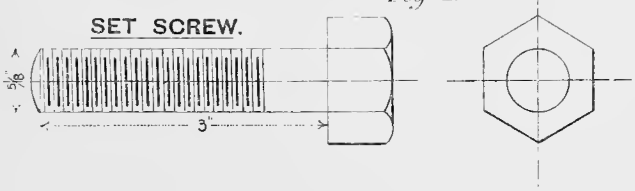
Fig 4.

WROUGHT IRON BOLT AND NUT.

Scale 6" = 1 Foot.

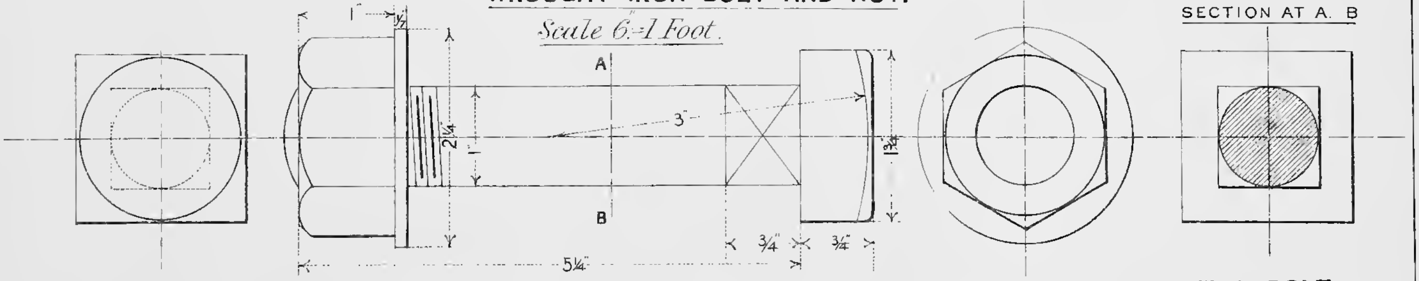
Fig 5.

VARIOUS METHODS OF LOCKING A NUT.

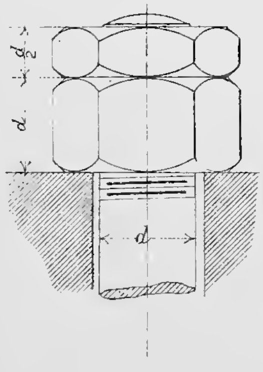
Fig 6.

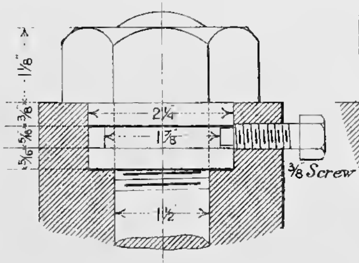
Fig 7.

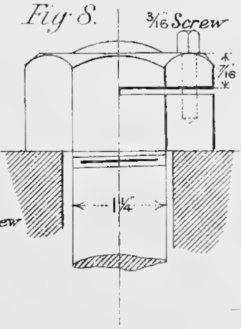
Fig 8.

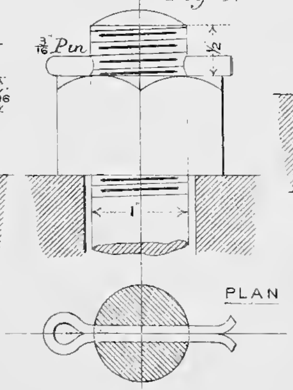
Fig 9.

STUD BOLT.

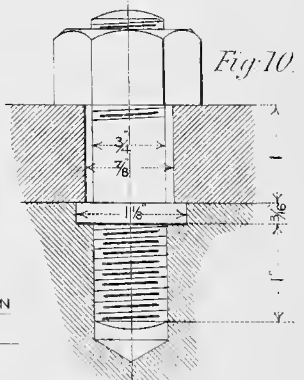
Fig 10.

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Plate VIII.—FOUNDATION BOLTS. KEYS FOR SHAFTS.

FOUNDATION bolts are employed for holding down cast iron machine frames or engine beds to stone or concrete foundations. The methods shown in Figs. 1 and 2 are used for light machines, and that in Fig. 3 for heavy vibrating machinery, such as engines, &c.

Fig. 1 represents a Rag bolt; the shank of the bolt is made of rectangular section and taper, and the edges are jagged or notched when red hot.

A hole is cut in the stone, the bolt placed in position, and fixed by filling the hole with molten lead. The objection to this method is that the bolt cannot be removed without destroying the stone.

Fig. 2 represents a Lewis bolt, one side is tapered, and the hole is cut in the stone to the required taper to fit it. To fix the bolt in position, it is dropped into the hole and a key is placed against the parallel side; when the bolt is drawn up by the nut it becomes wedged in the hole and so is held fast. The hole is deeper than the length of the bolt, leaving a clearance at the bottom, which facilitates its removal when required.

Fig. 3. The Cotter bolt is used where a heavy foundation is required to prevent the vibration of the machine. The head is formed by passing a cotter through the body of the bolt, which is increased in diameter to allow for the loss of metal in making the cotter hole. The foundations are built up of brickwork, a hole 3″ square being left for the bolt. The machine rests on stones placed on the top of the brickwork, round holes being made through the stones for the bolts. To place the bolt in position, the cotter is removed and the bolt passed down through the foundation; the cotter is then fixed in the bolt, suitable handholes being left for this purpose. A cast iron foundation plate acting as a washer distributes the pressure due to the tension in the bolt. In the drawing the brick foundations are not shown.

Keys, which are made of wrought iron or steel, and of rectangular section, are used for fastening pulleys, wheels, cranks, &c., to shafts, so that they may rotate with the shafts as one piece.

The sides are parallel, but the thickness varies uniformly; in good work the *taper* should be 1 in 100 or about $\frac{1}{8}''$ per foot. See Fig. 6.

Keys may be divided into three classes: 1. Hollow or Saddle key; 2. Keys on flat; 3. Sunk keys.

Fig. 7 shows a Saddle key, which is use for fixing light pulleys to turned shafts. A key way is cut in the boss of the pulley, and one face of the key is hollowed out to fit the shaft. In this arrangement the shaft and pulley are held together by friction alone, but the pulley can be easily moved to any part of the shaft. A head is placed at the thick end of the key for the purpose of "slackening back" when the other end is inaccessible. See Fig. 6.

The "key on flat" differs from the hollow one, in that a flat equal in width to the key is made on the shaft, parallel to its axis.

Fig. 8 shows a Sunk key, which is usually adopted where a great amount of power has to be transmitted. A key way is cut in both wheel and shaft, the key fitting sideways exactly. This key is subjected to a shearing stress, and produces compressive stress on the sides of the key ways. The wheel, being generally made of cast iron, should have a deeper key bed, since cast iron is more brittle than steel or wrought iron (see section of key Fig. 4).

The cross sections of keys are proportioned to the diameter of the shaft. There is no universal method for these proportions adopted by engineers.

Figs. 4 and 5 show graphic constructions for the proportions given by Reuleaux.

For sunk keys (breadth) $B = \frac{D}{5} + \frac{3}{16}''$ – (maximum thickness) $T = \frac{D}{10} + \frac{3}{16}''$.

„ saddle „ „ $B = \frac{D}{7} + \frac{1}{4}''$ – „ $T = \frac{D}{12} + \frac{3}{16}''$.

D = diameter of shaft; all dimensions in inches.

The dimensions for the keys are given full size, although in Fig. 4 the diameters are not so.

In tool work the keys are often made square in section. See Plates XXXIV and XXXV.

Fig. 9 shows a Feather key, which is used when the piece rotates with the shaft, but is capable of moving along its length. The key in this case is not tapered and must be secured to the shaft. An example of this is given in Fig. 3, Plate XII.

Fig. 10. Large pulleys, fly wheels, &c., are "staked on" the shaft; the hole is cast larger than the diameter of the shaft; key flats are cut in the boss and on the shaft. The keys are then fitted until the wheel is exactly true with the shaft. The proportion given in Fig. 4 is used in this sketch.

Fig. 11. A round pin fitted in a hole, drilled half way into shaft and wheel boss is here shown.

EXERCISES.

1.—Draw Figs. 1 and 2 *full size* and add plans. *Note.*—The cast iron plate and stone are shown in section and the bolt not in section.

2.—Draw the cotter bolt *full size*, as shown. Add a view looking at the end of the bolt, to show the foundation plate and cotter. Make the plate square.

3.—Determine, from Fig. 4, the dimensions of a sunk key for a 6″ shaft, and also the depth of the key way in the shaft.

FOUNDATION BOLTS.

Scale 1/3 full size.

RAG BOLT.

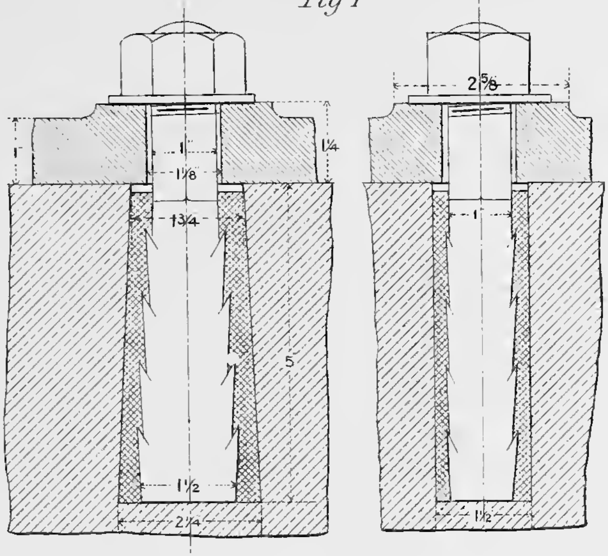


Fig 1

LEWIS BOLT.

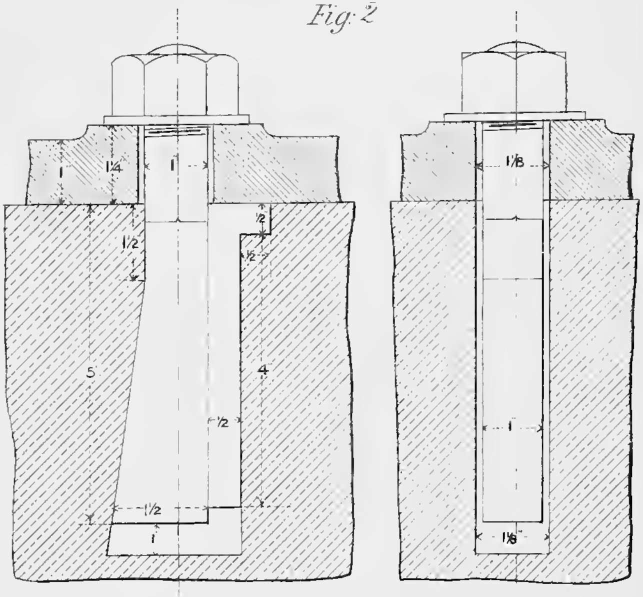
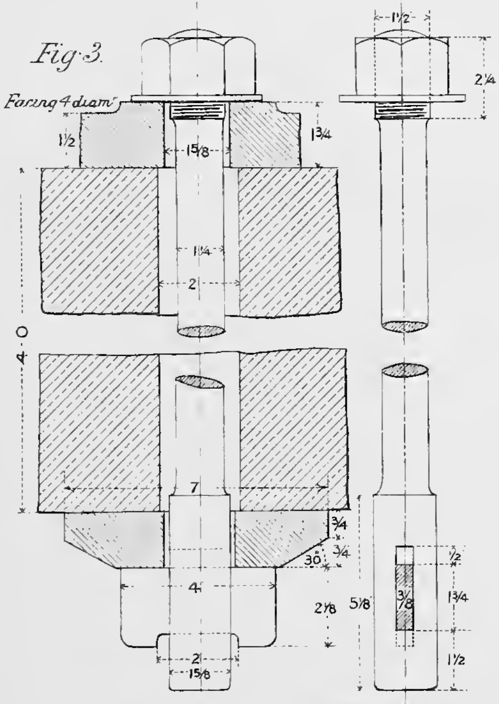


Fig 2

COTTER BOLT.

Scale 1/3 full size.

Fig 3.



KEYS FOR SHAFTS.

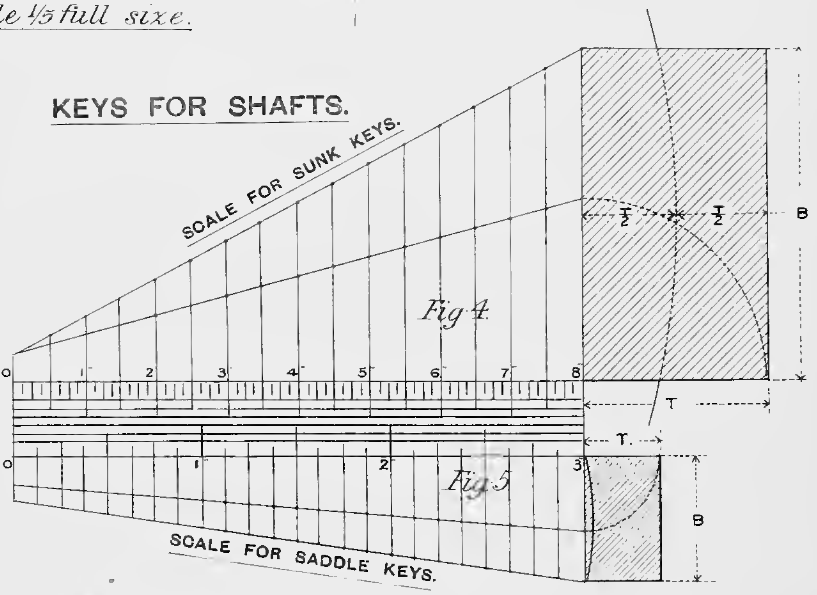


Fig 4.

Fig 5

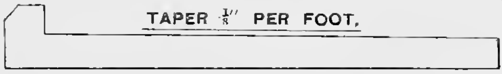


Fig 6.

SADDLE KEY.

KEY ON FLAT.

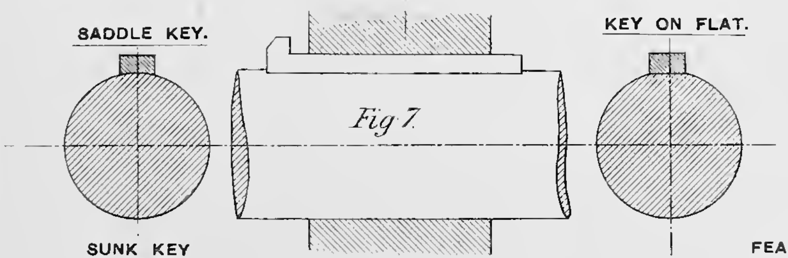


Fig 7.

KEYS FOR STAKING ON

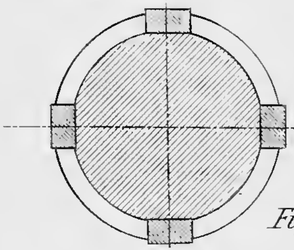


Fig 10.

ROUND KEY.

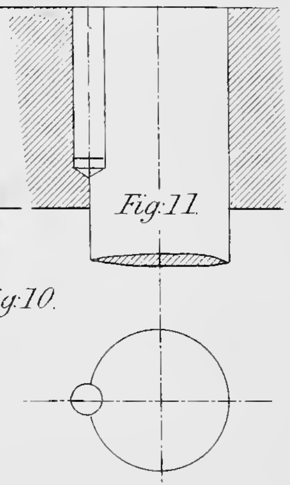


Fig 11.

SUNK KEY

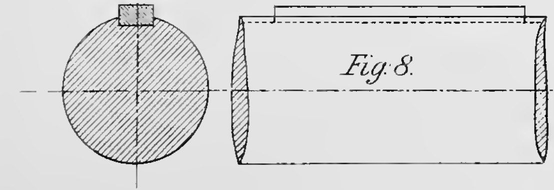


Fig 8.

FEATHER KEY.

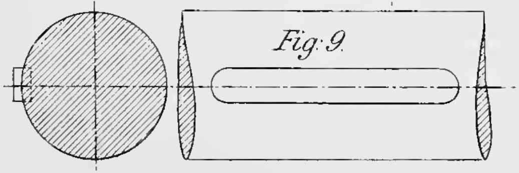


Fig 9.

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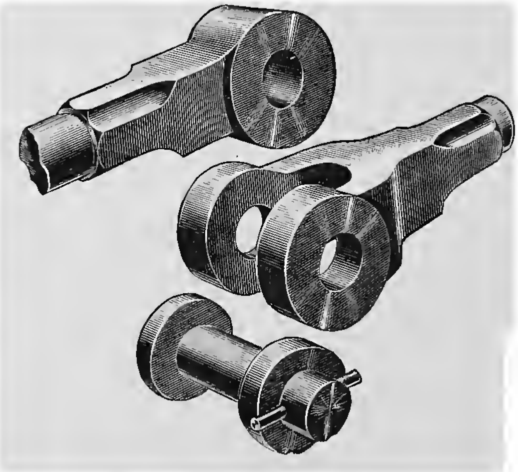
Plate IX.—JOINTS AND CONNECTIONS.

FIG. 1 shows elevation and sectional plan of a joint for two belts of wrought-iron or steel plate. A cover piece is riveted to the ends of the plates. The rivets through which the section plane passes, being cylindrical, are not shown in *section.* This is usually done where a section is made of a part, and the section plane passes through the axis of a round pin or shaft.

Fig. 2. An adjustable joint for two pieces of round section is here given. One piece is screwed with a *right hand* thread and the other with a *left hand* one. A double ended steel nut connects them together. The body of the nut is hexagonal, of the same size as the standard nut used for bolts. A clearance is left in the centre of the nut to reduce the amount of tapping.

Fig. 3 represents one method of connecting round wrought-iron rods, such as well pump rods, by means of a scarfed joint. The ends are enlarged and shaped as shown. A wrought-iron box or sleeve fits over the joint, keeping the parts in position. The pull or thrust on the rod is transmitted through the shoulders of the joint.

Fig. 4 shows a cottered joint; the ends of the rods are bossed, so that the area across the cotter hole may be equal to that of the solid part of the rod. The two rods which butt together are held in position by the steel cotters. Clearance, as shown, must be left in the cotter holes of the rods and coupling piece, to allow for the draw of the cotters.



Figs. 5 and 6. Hooke's coupling or universal joint is used for the transmission of rotation from one shaft to another, when their axes intersect. The wrought-iron forked pieces A and C are keyed to the ends of the shafts, and connected at right angles to each other, by means of bolts passing through the central wrought-iron piece B. The angular velocity ratio is continually varying, but four times in each revolution the two shafts are rotating at the same velocity.

Fig. 7 gives three views of a knuckle joint for wrought-iron or steel rods. It is made up of three parts, as shown in the accompanying illustration. The round pin is made with a head at one end, the other one being formed by a thick loose washer, held in position by a taper pin.

EXERCISES.

1.—Draw Fig. 1, adding an end elevation. *Scale 6″ = 1 foot.*

2.—Draw the views given in Fig. 2, and add end, and sectional end elevations. *Scale ¾ full size.*

3.—Draw the Sectional elevation and plan of the scarfed joint as given. Show an end elevation looking towards the small end. *Scale 9″ = 1 foot.*

4.—Draw Fig. 4 *full size,* and show a cross section through a cotter.

5.—Draw the two views of Fig. 5 as given, adding a plan and an end elevation looking in the direction of the fork C. *Scale 6″ = 1 foot.*

6.—Draw and complete three views of Fig. 7, showing also the other end elevation. *Scale ½ full size.*

QUESTIONS.

1.—Distinguish between a key and a cotter. Draw an example of each, stating the purpose for which each is employed.

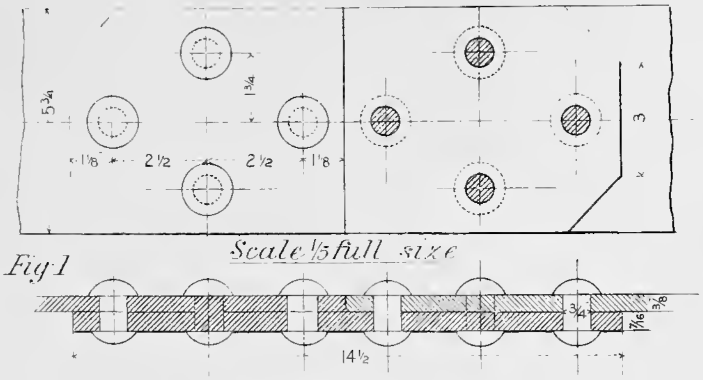
2.—In Fig. 4, assuming that the shearing strength of a cotter is equal to the tensile strength of a rod, determine which would first yield under a pull.

3.—Give an example of the application of Hooke's joint, and explain how the variable angular velocity ratio may be neutralised.

PLATE IX.

VARIOUS JOINTS AND CONNECTIONS.

JOINT FOR FLAT PLATES.



Scale ⅕ full size

Fig 1

ADJUSTABLE JOINT FOR ROUND RODS.

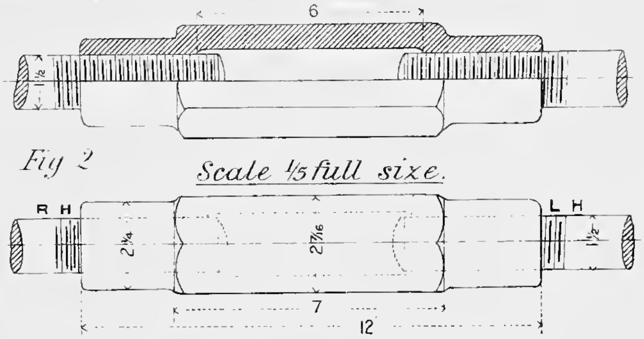


Fig 2

Scale ⅕ full size.

SCARFED JOINT.

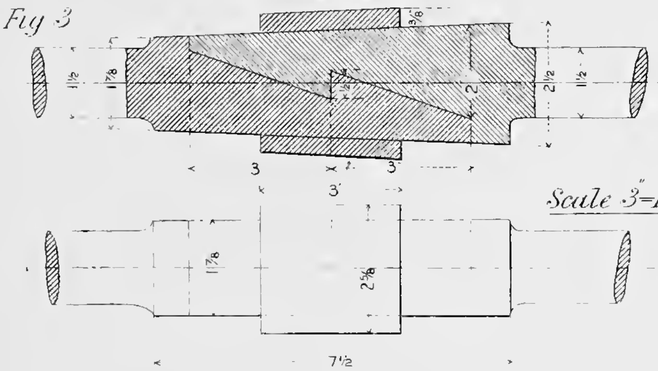


Fig 3

Scale 3"=1 Foot

COTTERED JOINT FOR ROUND RODS.

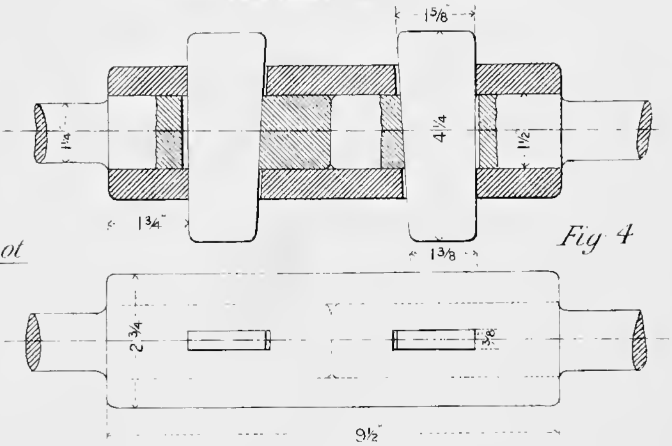


Fig 4

HOOKE'S UNIVERSAL JOINT.

Scale 3"=1 Foot

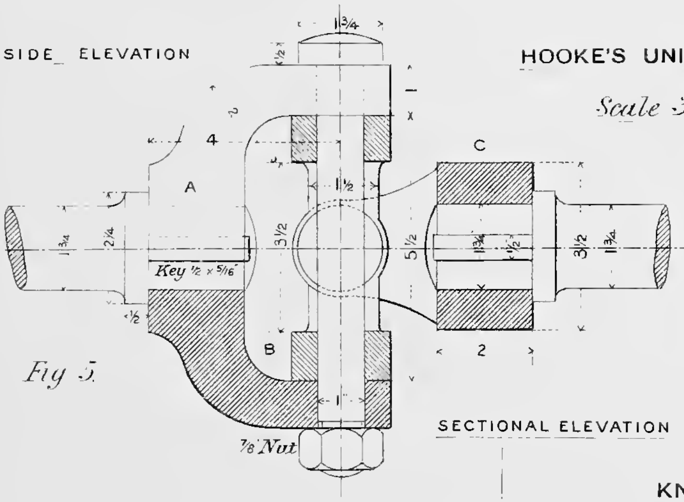


Fig 5

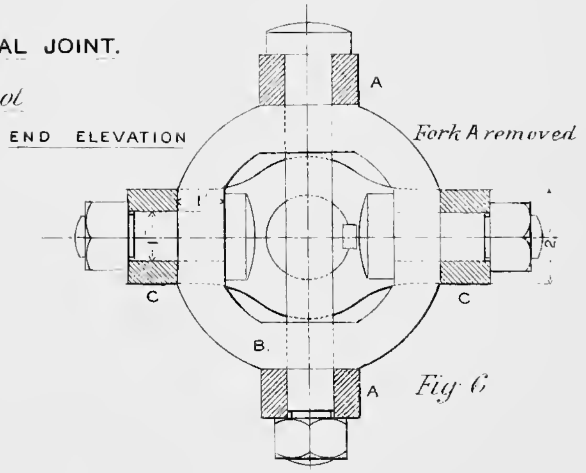


Fig 6

KNUCKLE JOINT.

Scale 3"=1 Foot

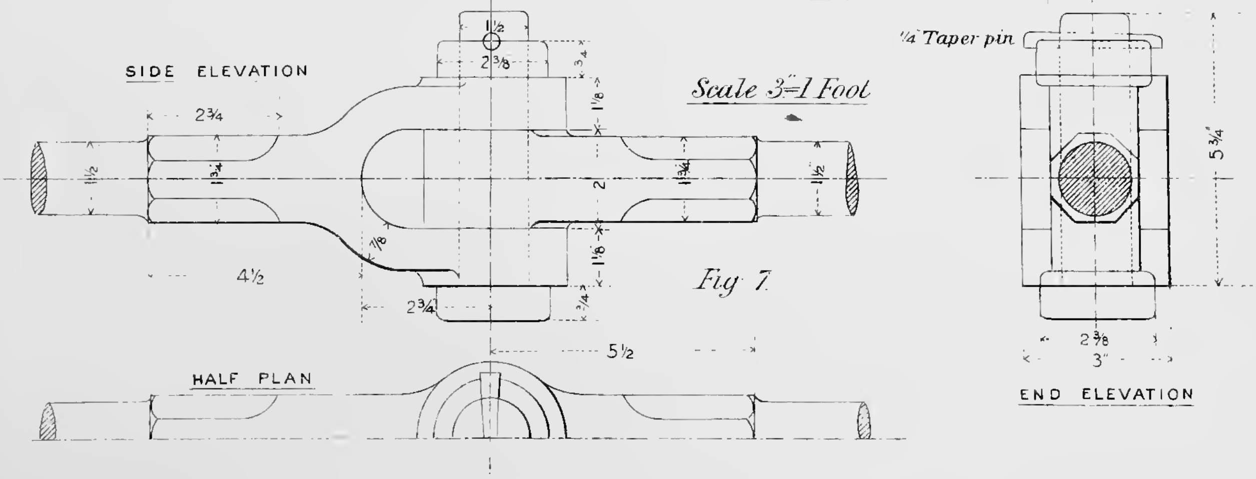


Fig 7

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Plate X.—CAST IRON PIPES AND JOINTS.

*FIG. 1 gives two views of a cast iron steam or water pipe connected together by wrought iron bolts, passing through flanges. The flanges are discs of metal cast on the body of the pipe. They are turned or faced up by a machine, so that, when placed in contact, or jointed, the axes of the pipes are in one straight line. The joint is made water or steam tight by placing between the faces of the flanges a thin disc of india rubber. In some cases cement is used as a packing. The body of the pipe is made a little thicker near the flanges.

***Fig. 2.** The socket joint is used where it is required to be slightly flexible, as in the case of gas and water pipes laid in the ground. A is the spigot end and B the socket end. The joint is made by coils of tarred rope driven tightly into the socket end, and a ring of lead is cast in the mouth of the socket, which ring is held in position by the groove as shown.

***Fig. 3** is an example of an ordinary cast iron pipe showing a branch and elbow, both of which are used for the purpose of connecting pipes at right angles to it.

The branch pipe joins into the main pipe, as shown in the elevation by straight lines, this being the special case of the intersection of two cylinders, of the same diameter. See Plate III.

EXERCISES.

1.—The given views of the cast iron flanged joint are to be drawn, adding a plan. *Scale 9″ = 1 foot.*

2.—Draw the socket joint as given in Fig. 2. *Scale $\frac{5}{8}$ full size.* The student must draw his own scale for this exercise.

3.—Draw the three views given in Fig. 3 and add another end elevation. *Scale 3″ = 1 foot.*

*Note.—These examples are shown partly in section and partly in elevation. This is often done, and is quite as good as two complete drawings.

HINTS ON MAKING A DRAWING.

Most machine parts are made symmetrical about a central line or axis. Generally the centre line is the first one made in commencing a drawing. When circles occur in any of the views they should be drawn first. The projections of these circular parts in the other views may be found by the T or set square, without measuring again from the scale or rule. No circle should be drawn until its centre has been fixed by making two lines at right angles to each other. Sometimes the first line made in the drawing is a base or ground line.

As a rule one view cannot be completed before the others are commenced; portions of each are made in turn, and the drawing gradually developed by passing from one view to the other.

No definite general instructions can be given in the matter; judgment must always be exercised, and experience is the best guide.

All lines in the drawing should be clear and thin until it is completed. The drawing may then be *lined in*, either in indian ink, or by pencil, as desired.

Centre lines should always be thin full lines, and not dotted, as shown in the drawings.

PLATE X.

CAST IRON PIPES AND JOINTS.

FLANGED JOINT.

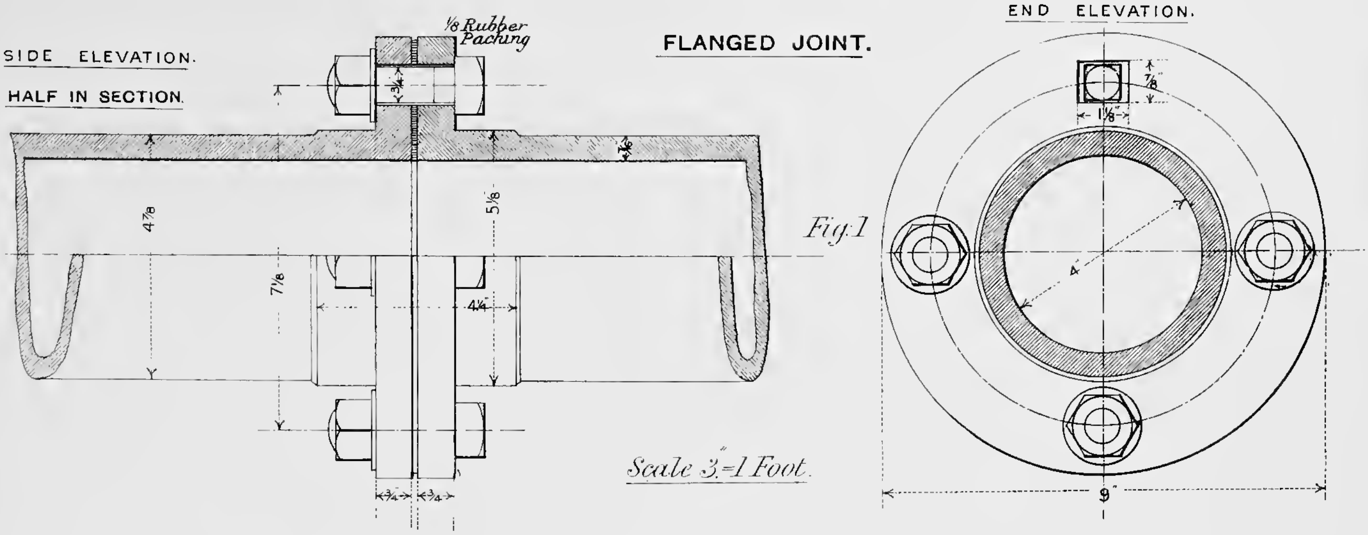

Fig. 1.

Scale 3"=1 Foot.

SOCKET JOINT.

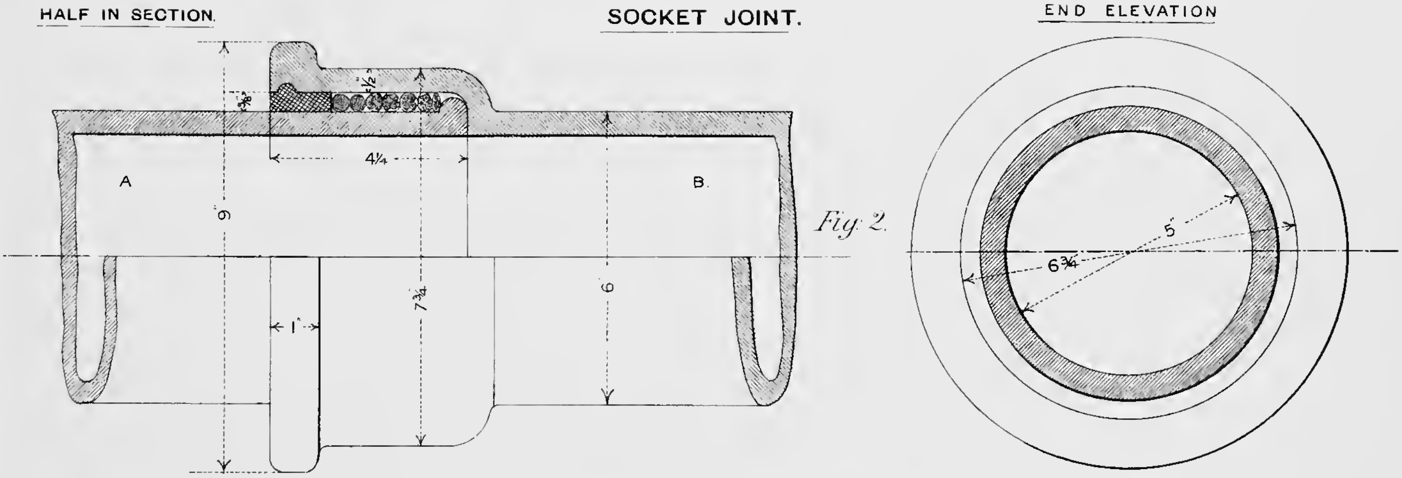

Fig. 2.

BRANCH AND ELBOW PIPE.

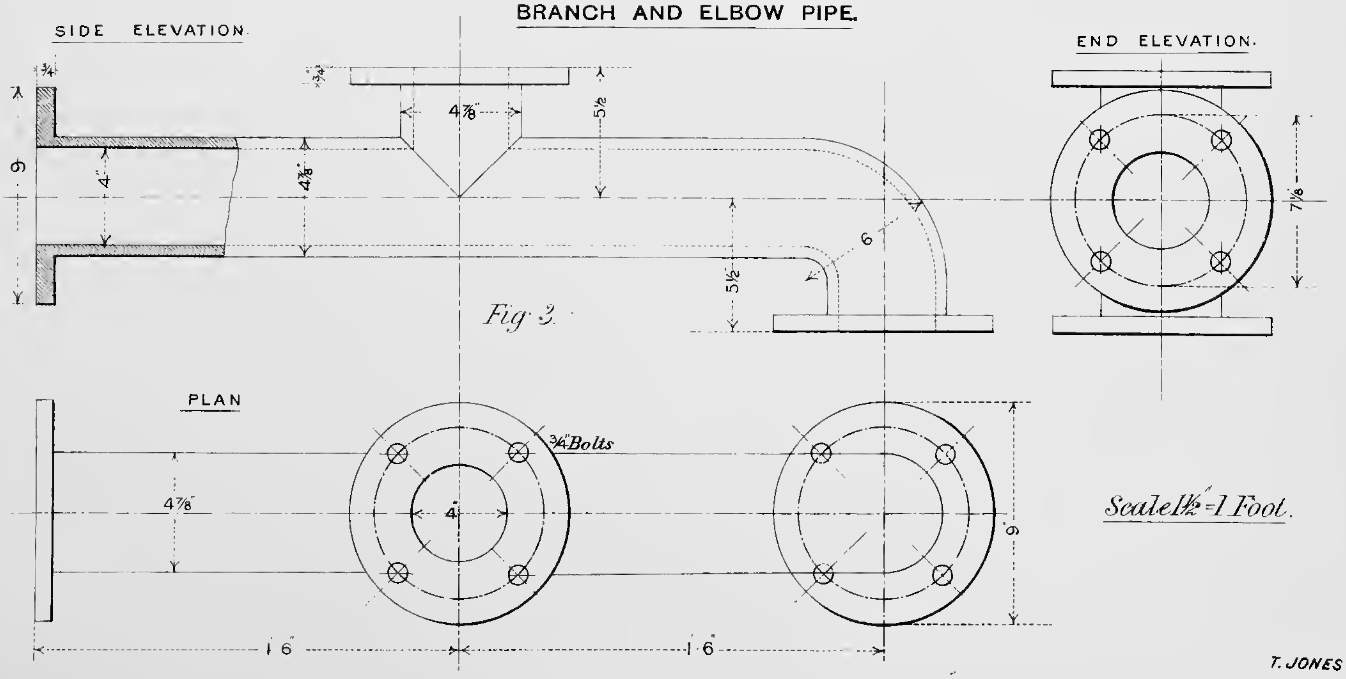

Fig. 3.

Scale 1½"=1 Foot.

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Plate XI.—HYDRAULIC PIPE JOINTS.

HYDRAULIC pipe joints are of special construction, since they have to withstand great pressures up to 3 tons on the square inch. In ordinary steam pipes, 200 lbs. on the square inch is about a maximum. Packing-rings, which are made of some yielding substance, are always placed between the jointed surfaces, since it is impossible to bring these surfaces into exact contact.

Figs. 1 & 2. In this form of joint for cast iron pipes, the flanges are turned true, the projection on one pipe fitting exactly into the recess in the other. A gutta percha ring is used as a packing.—See Fig. 2. Two wrought iron bolts are required to hold the pipes together. One half of the end elevation shows the face of the flange.

Fig. 3 shows a joint which is used for wrought iron or steel pipes of small diameter. The end of one pipe is screwed as shown, and the end of the other has a small flange forged on it. A gutta percha packing-ring is placed between the jointed surfaces. These are drawn together by the nut which screws on to one pipe and acts against the flange on the other one.

Fig. 4. Solid drawn steel tubes or pipes are jointed together as shown in this drawing. Steel flanges of the form given, are screwed on the ends of the tubes. The end of one pipe fits into the flange of the other one. These ends form the jointed surfaces, and they are grooved so that the lead packing-ring may be pressed into them, when the pipes are drawn tightly together by the steel bolts.

EXERCISES.

1. Draw the hydraulic pipe joint Fig. 1, ¾ *Full Size;* add an end elevation, looking in the direction of the nuts. Show also a complete plan.

2. Draw the joint Fig. 3. Add a complete plan, and the end elevation looking in the opposite direction to the given one.—*Scale Full Size.*

3. Draw Fig. 4 as given in the drawing, and add a plan projected from the end elevation.—*Scale 9″ = 1 Foot.*

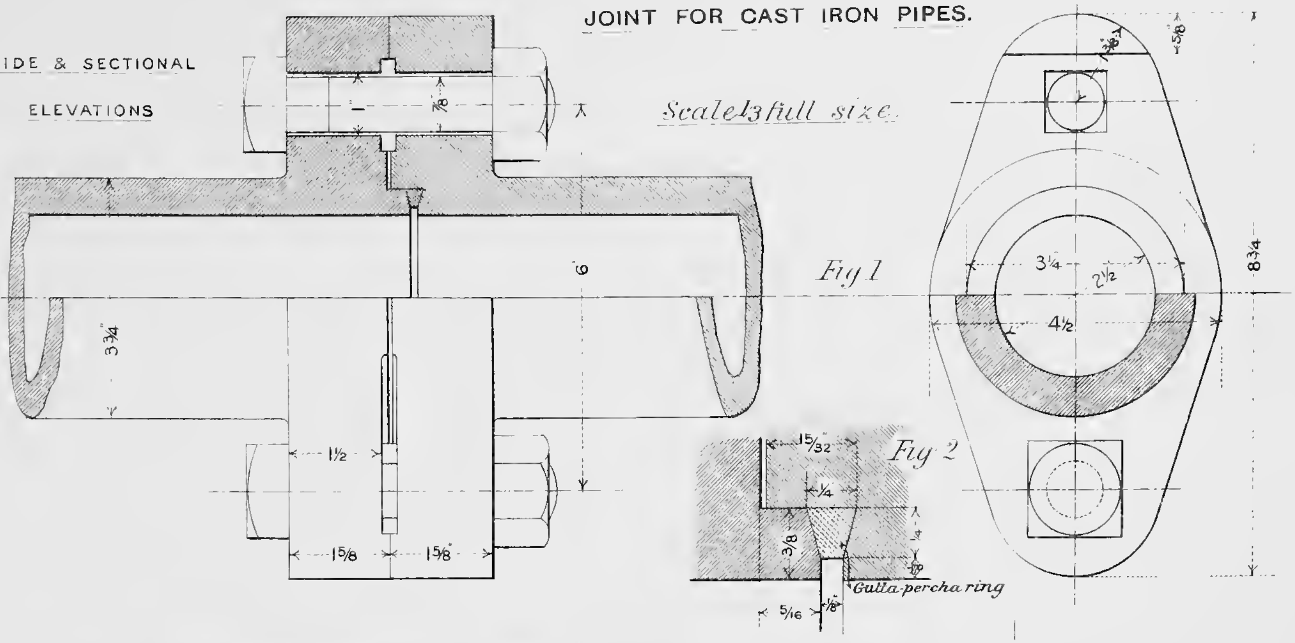
HYDRAULIC PIPE JOINTS.

JOINT FOR CAST IRON PIPES.

SIDE & SECTIONAL ELEVATIONS

END ELEVATIONS.

Scale 1/3 full size.



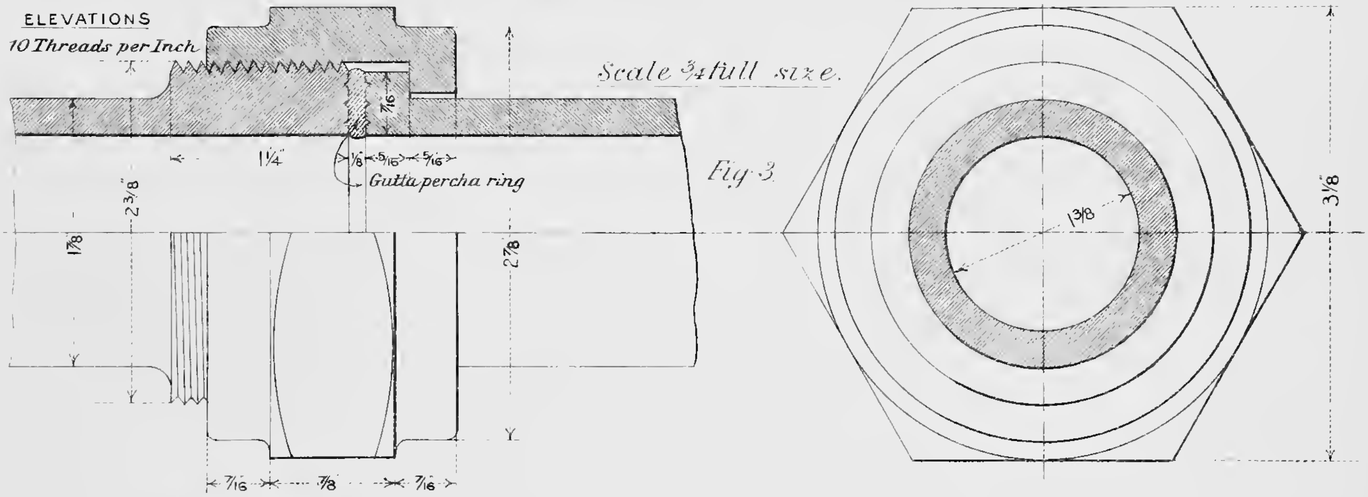
JOINT FOR SMALL WROUGHT IRON PIPES.

SIDE & SECTIONAL ELEVATIONS

END ELEVATION

10 Threads per Inch

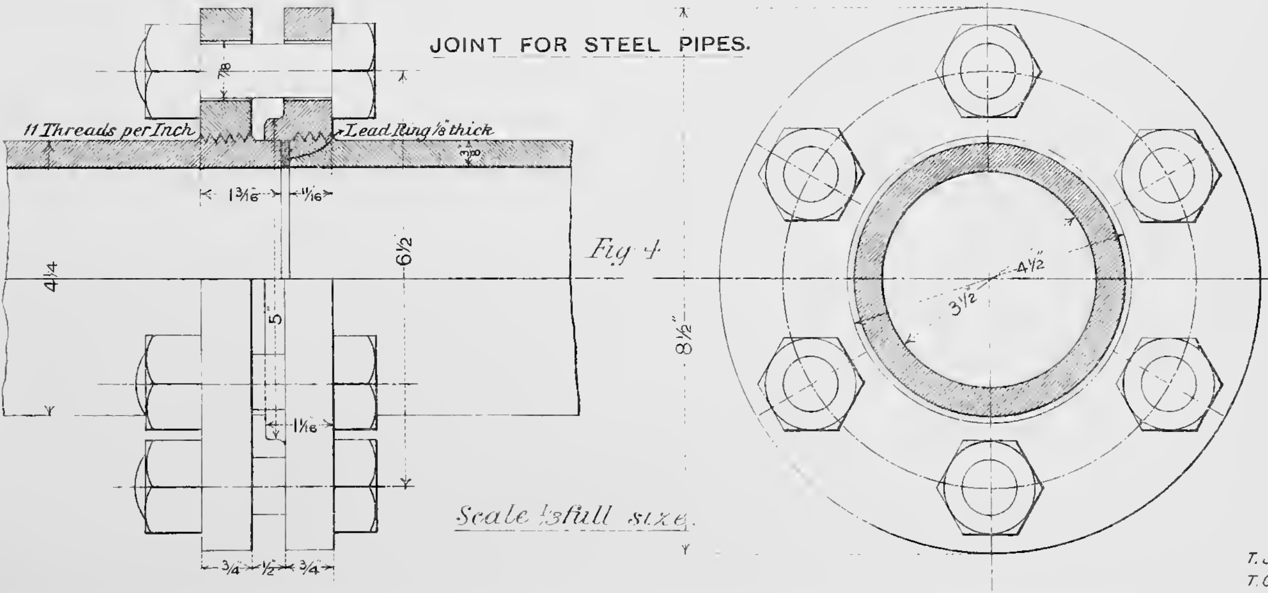
Scale ¾ full size.



JOINT FOR STEEL PIPES.

SIDE AND SECTIONAL ELEVATIONS.

END ELEVATION



Scale 1/3 full size.

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Plate XII.—SHAFT COUPLINGS.

THE three couplings given in this Plate are those used for connecting two lengths of shafting together whose axes are coincident. The **Box** and **Flange** couplings are called Fast or Permanent, and the **Claw** coupling a disengaging one. A bearing should always be placed as near as possible to a coupling.

Fig. 1 shows a Box coupling which may be used for shafts of small diameters. The shaft ends B and C, which are enlarged or *bossed*, butt together. A cast iron cylindrical box or muff is bored to fit the shafts, and holds them together by means of a key sunk half way into the shafts and coupling. See Plate VIII. for taper of the key.

Fig. 2. The Flange coupling is represented by four elevations, half of each being shown. It consists of two cast iron discs or flanges, A and B keyed to the ends of the shafts, and held together by bolts. The whole power of the shaft is transmitted through these bolts, which are in shear. The face of the flange is usually turned true on its own shaft, a projection being left on one flange which fits into a recess in the other one.

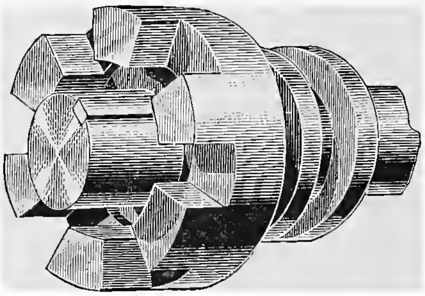
This brings the shafts exactly in line with each other when the flanges are bolted together. The ends of the shafts are often bossed up for the coupling. The backs of the flanges are dished, so that the bolt heads and nuts do not project beyond their edges.

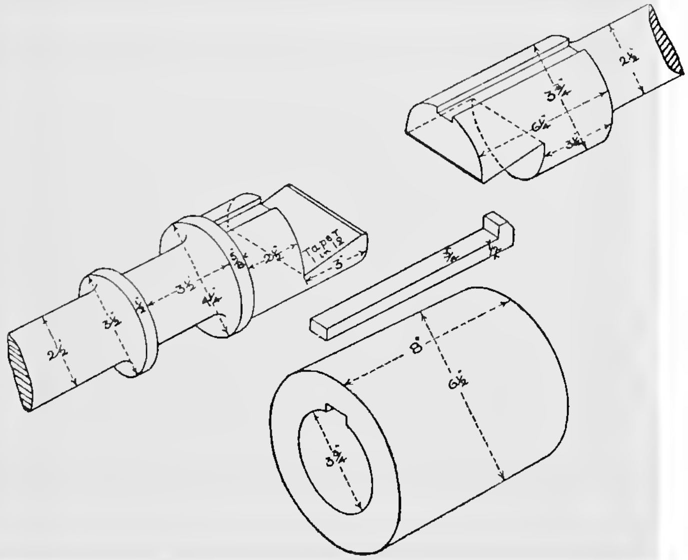
Fig. 3 shows a form of coupling which is often used for slow running main driving shafts, placed below the ground floor.

The shafts are easily disconnected, which is a great advantage in a mill where one part is required to run at night when the remainder is stopped.

The shaft ends butt together. On the shaft C, one half the coupling E is keyed fast. The other half F slides upon D on a feather key. The piece F is provided with a groove, into which the forked end of a lever fits, for moving it in and out of gear with E.

Projections are cast upon E and F. The projection on E fits into the recesses on F, and vice versa. The accompanying illustration shows the part F on the shaft D. The side elevation of the teeth must be projected from the section.





EXERCISES.

1.—Draw the given views of the Box Coupling, and add a plan and cross section through the centre of the box. *Scale* $\frac{3}{4}$ *full size.*

2.—Draw a *complete* sectional elevation of Fig. 2, and the end elevation as shown. Add a plan and an end elevation looking towards the bolt heads.
Scale $\frac{3}{8}$ *full size.*

3.—Draw the two views of Fig. 3 as given. Add an end elevation of E and a plan showing F in section.
Scale 3″ = 1 foot.

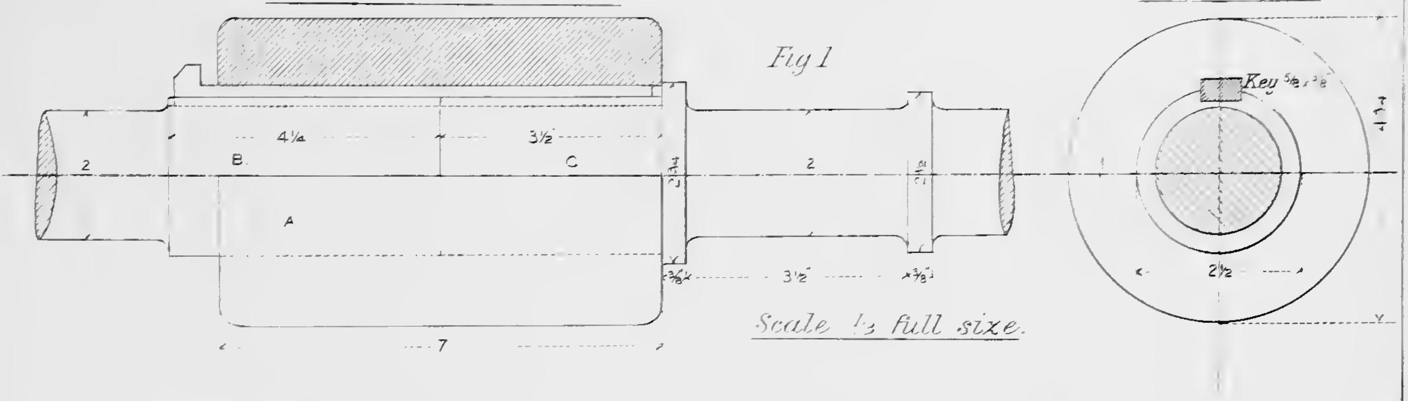
4.—Draw complete sectional elevation, plan and end elevation of the half lap coupling shewn in the isometric sketch. *Scale 6″ = 1 foot.* Note.—The coupling must be fitted together.

SHAFT COUPLINGS.

BOX COUPLING.

SIDE AND SECTIONAL ELEVATIONS

END ELEVATION

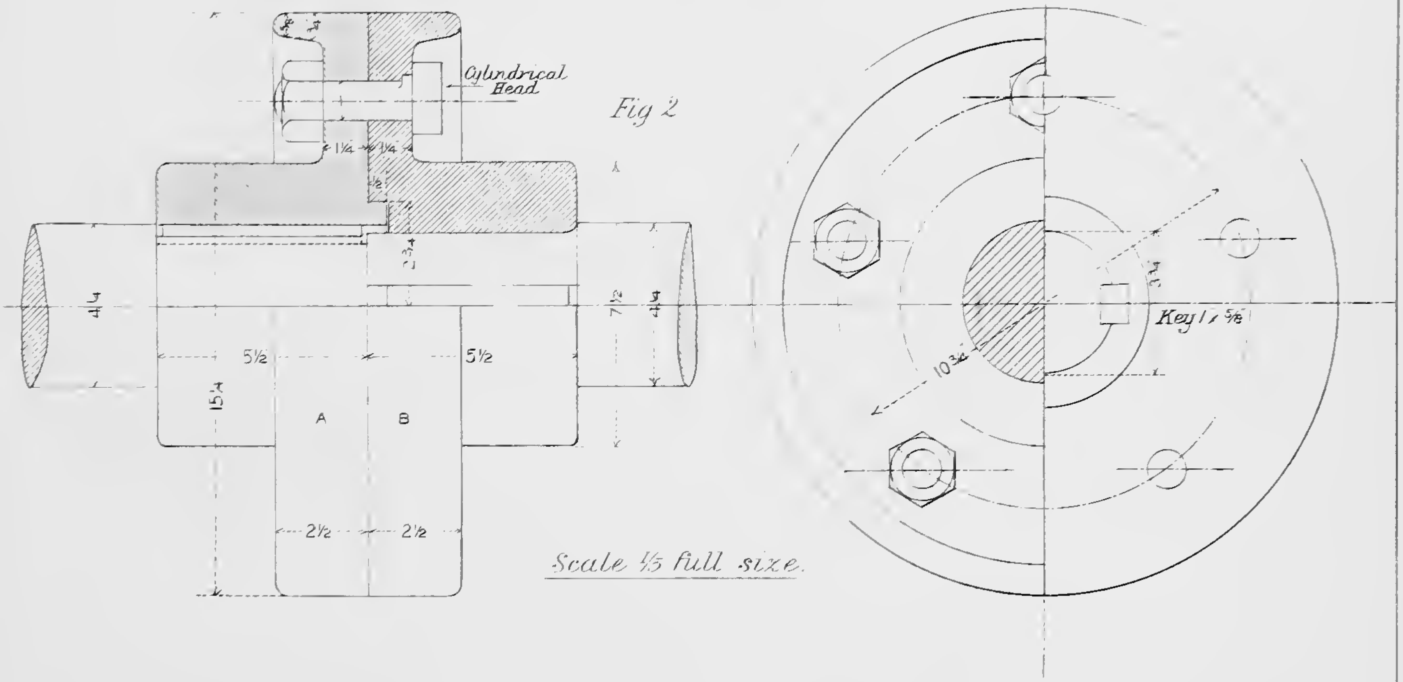


Scale ⅓ full size.

FLANGE COUPLING.

SIDE & SECTIONAL ELEVATIONS.

END ELEVATIONS.

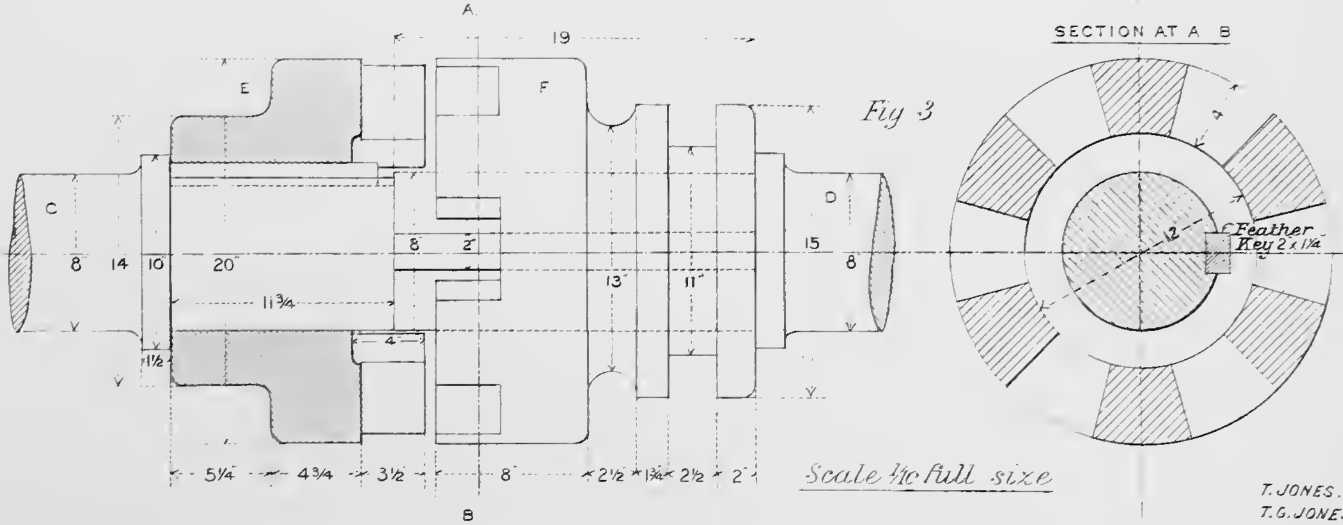


Scale ⅕ full size.

CLAW COUPLING.

SIDE & SECTIONAL ELEVATIONS.

SECTION AT A B



Scale 1/10 full size

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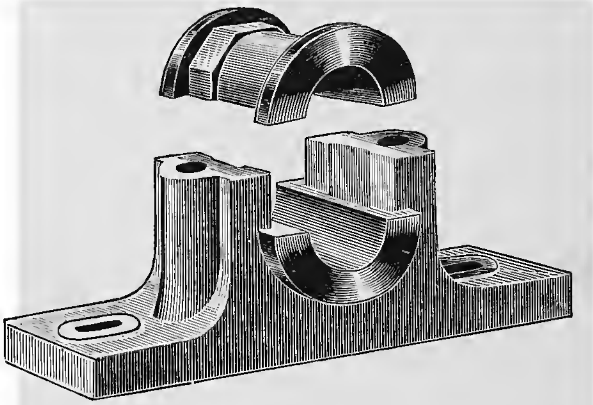
Plate XIII.—PEDESTAL AND FOOTSTEP BEARING.

A PEDESTAL is used for supporting a rotating shaft. The portion of the shaft which rests in the pedestal is called a journal. In a line of shafting it is usual to boss the shaft at the end through which the power is communicated. The journal, or neck, is turned into this boss, leaving collars which fit against the faces of the pedestal brasses, and so prevent the shaft from moving endways.

A pedestal consists of the following parts (see Fig. 1): (1) the cast-iron body **C**; (2) the gun metal steps or brasses **E** and **F**; (3) the cast-iron cap **D**; (4) the wrought-iron bolts for holding the cap and steps in position. The pedestal is carried in various ways—by a cast-iron wall box or bracket, as shown in Plate XIV., by a cast-iron standard, as shown in Plate XVI., and in many other ways.



The steps in small pedestals are made in two parts, as shown in the illustration and in Fig. 1. This is necessary for two reasons. The shaft can be readily fixed or removed, and the steps can be adjusted for wear. The wear on the steps is minimised by lubrication, and in cases where the load on the shaft is very great, the bearing is increased in length. This reduces the pressure per square inch on the surface.

Fig. 1 shows one form of pedestal for a shaft 3″ diameter. The body is planed on the base, so as to rest accurately on the carrier to which it is attached, by the bolts passing through the holes cast in the base. The steps fit into recesses in the body and cap respectively. Fitting strips are placed in these recesses to lessen the amount of labour in fitting, as shown in the accompanying illustration of the cap. The steps are prevented from rotating with the shaft by being made octagonal in shape. Other methods of preventing rotation are shown in Fig. 2.

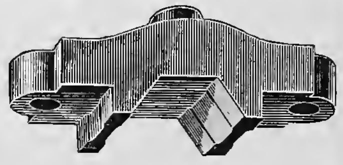


Fig. 3 shows a footstep bearing for a vertical shaft 3″ diameter. The end of the shaft is fitted with a steel disc, which rests and revolves on another one, fixed on the bottom of the footstep bearing. The latter disc is made slightly conical on the underside to allow a little adjustment, if the shaft end is not perfectly true.

The cast-iron body **A** is cored out and then bored to receive the brass bush **B**, which is turned to fit the hole at the top and bottom only.

EXERCISES.

1.—Draw the three views of the pedestal given in Fig. 1. *Scale ¾ full size.*

2.—Make good freehand sketches of the steps given in Fig. 2 about twice the size.

3.—Draw the views as given in Fig. 3, completing the plan. *Scale* 8″ = 1 *foot.*

QUESTIONS.

1.—Sketch two views of a simple form of pedestal with brass steps, and explain the use of the cap.

2.—Sketch the brasses for a bearing, and show how they are prevented from turning in the pedestal.

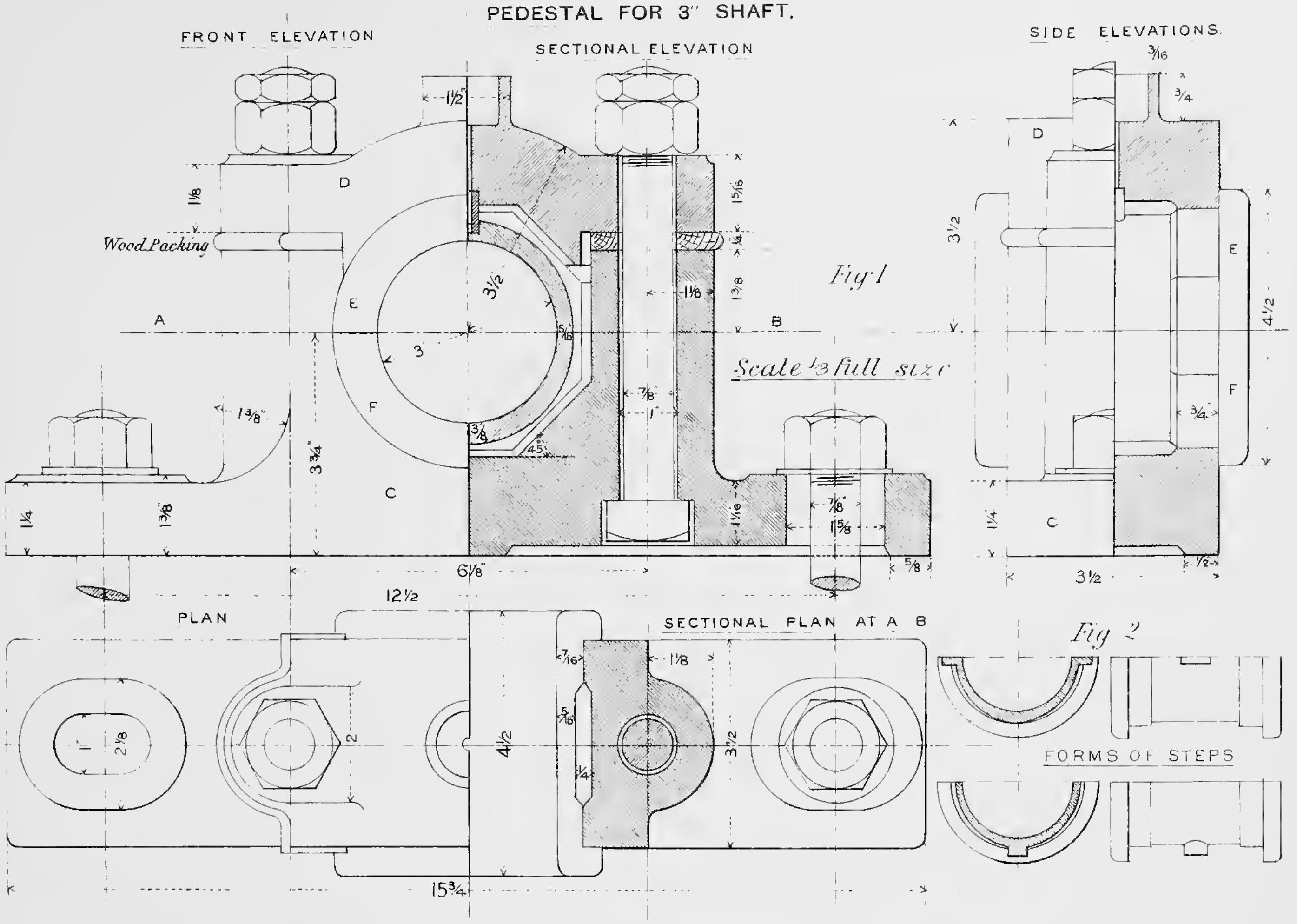
3.—Explain why a soft metal like brass is used for bearings.

4.—What are fitting or chipping strips? Give sketches showing where they are used, and explain why they are used.

5.—Why are the steps in the pedestal Fig. 1 separated horizontally?

SHAFT BEARINGS.

PEDESTAL FOR 3" SHAFT.


FRONT ELEVATION

SECTIONAL ELEVATION

SIDE ELEVATIONS.

Fig 1

Scale 1/3 full size

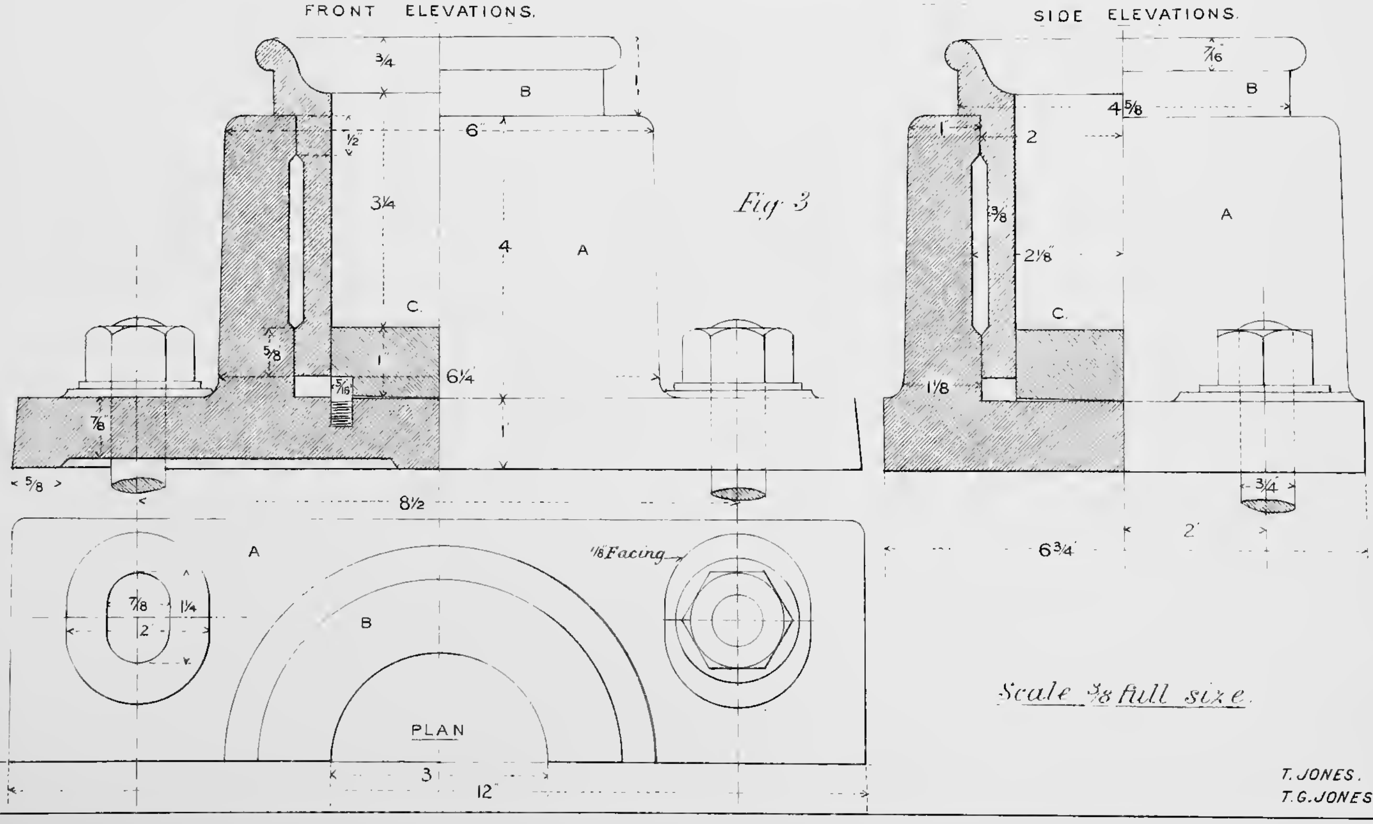
PLAN

SECTIONAL PLAN AT A B

Fig 2

FORMS OF STEPS

FOOT-STEP FOR VERTICAL SHAFT.


FRONT ELEVATIONS.

SIDE ELEVATIONS.

Fig 3

PLAN

Scale 3/8 full size.

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Plate XIV.—HANGER, WALL BOX, AND WALL BRACKET.

HANGERS are used for carrying light shafting for driving machines, which are placed in any part of the room not near the wall. They are bolted to the beams. Two forms are used, the J and the U. In some cases the latter is made a simple casting with the base of sufficient length to carry an ordinary pedestal. The chief objection to the U form is the difficulty of getting the shaft in and out of its place. The shaft has to be threaded through the hanger, which is, however, very rigid, and not so liable to vibrate as the J form. The latter has the advantage of being easy to fix, and the shafting is readily placed into position.—See Plate XV.

Fig. 1. Shows a form of U hanger, in which the casting forms the body of the pedestal carrying the shaft. It is fitted with brasses or steps which are held in position by the cap and bolts the same as an ordinary pedestal.

Fig. 2. A wall box is here given. This is used to carry a pedestal for a shaft which passes through a wall. The box is built into the wall and the pedestal is bolted to the shelf. The base of the pedestal is held between the snugs cast on the wall box, by wrought iron wedges. In rough work the base of the pedestal and the shelf of the wall box are not faced; a packing of soft wood is then placed between these surfaces.

Fig. 3. Shows a wall bracket which is used to carry a pedestal for a shaft running parallel to and near to a wall. The bracket is fastened to the wall by two wrought iron bolts which pass through it; large cast iron washers are placed under the bolt heads to distribute the pressure due to screwing up the nuts. A snug is cast on the bottom edge of the backplate. This, which is fitted into the wall, helps to carry the weight of the bracket and shaft, and takes the cross strain off the bolts. The friction between the back plate and the wall also assists in doing this. The pedestal fits on the shelf, and is fixed in the same way as to the wall box.

EXERCISES.

1. Draw the given views of the hanger, and add a plan and side elevation. *Scale 3″ = 1 foot.* Show a needle lubricator fitted to the cap.—See Plate XV.
2. Draw the two views given in Fig. 3, and also a sectional side elevation through the centre. *Scale 3″ = 1 foot.*
3. Draw the wall box, with the pedestal fixed in position. Show the wall box in sectional elevation, but the pedestal not in section. *Scale 3″ = 1 foot.*—See Plate XIII. for dimensions of pedestal.
4. Draw the two views of Fig. 4 as shown, and add an elevation looking towards the wall. *Scale 4″ = 1 foot.*
5. Draw the bracket as given in Exercise 4, showing the pedestal in position.

NOTES ON THE STRENGTH OF SHAFTING.

The strength of a shaft to resist a twisting moment, varies directly as the cube of the diameter, and directly as the number of revolutions.

The shearing stress on the material of the shaft increases uniformly from the centre, it being zero at the centre, and a maximum at the outside.

To determine the diameter of a shaft to transmit any given horse power, the twisting moment must first be found.

$$\left.\begin{array}{rl} \text{If } H = & \text{horse power;} \\ n = & \text{number of revolutions per min.} \\ T = & \text{twisting moment in inch lbs.} \end{array}\right\} \quad T = \frac{12 \times 33000 \times H.}{2\pi n.}$$

The diameter of a shaft d for a given twisting moment T, is expressed by $T = \frac{\pi d^3 f}{16} \therefore d^3 = \frac{16\,T}{\pi f}$ where f is the maximum shearing stress in the material. $f = 8000$ lbs for wrought iron, and 10,500 for mild steel.

When the shaft is also subjected to a bending moment; the equivalent twisting moment T_e is found by the following formula. $T_e = M + \sqrt{T^2 + M}$; where M = maximum bending moment.

$$\text{Then } T_e = \frac{\pi d^3 f}{16} \text{ and } d^3 = \frac{16\,T_e}{\pi f}$$

The following *approximate* formula may be used :—

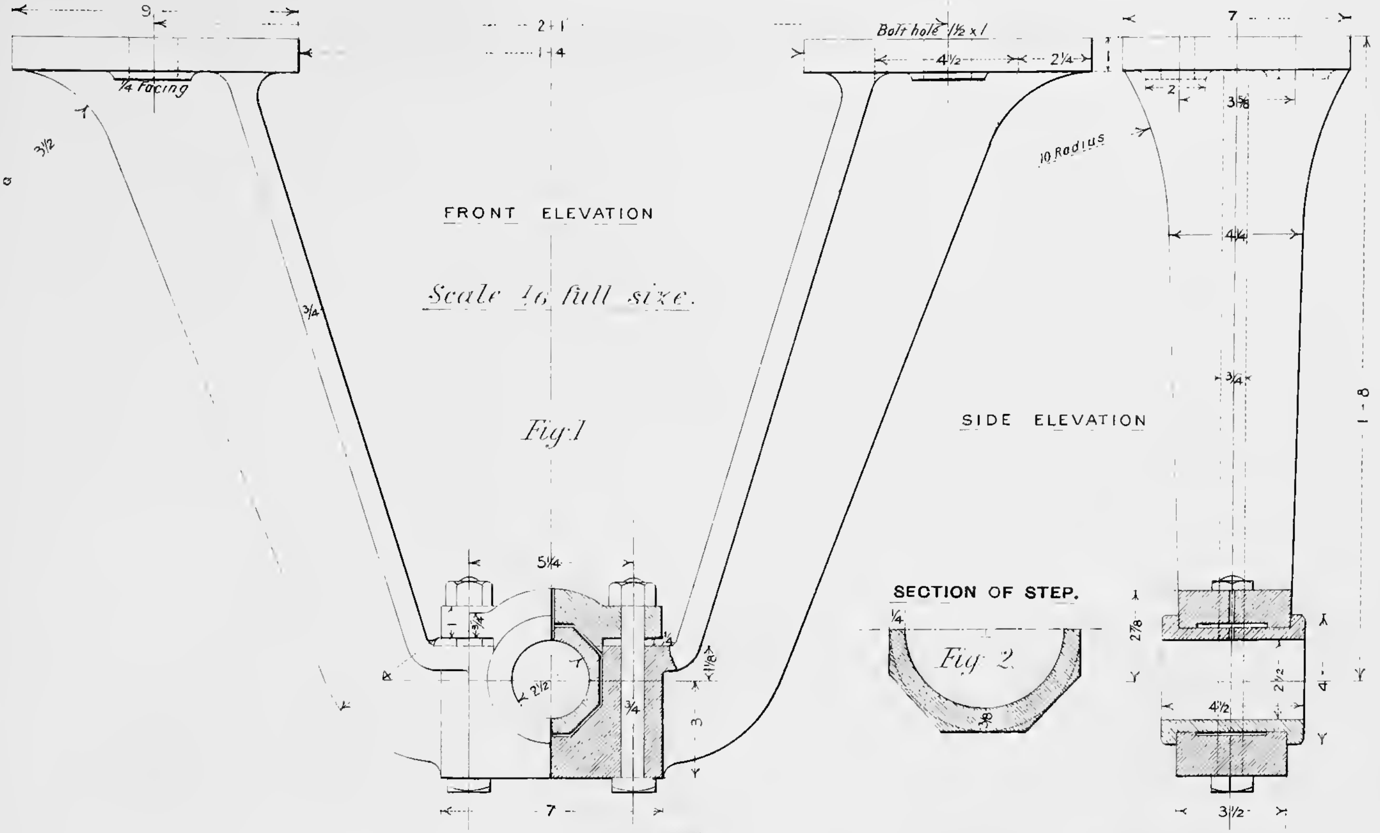
$$H = \frac{d^3 n}{80} \text{ for quick running shafts of small diameter.}$$

$$H = \frac{d^3 n}{100} \text{ for second motion shafts.}$$

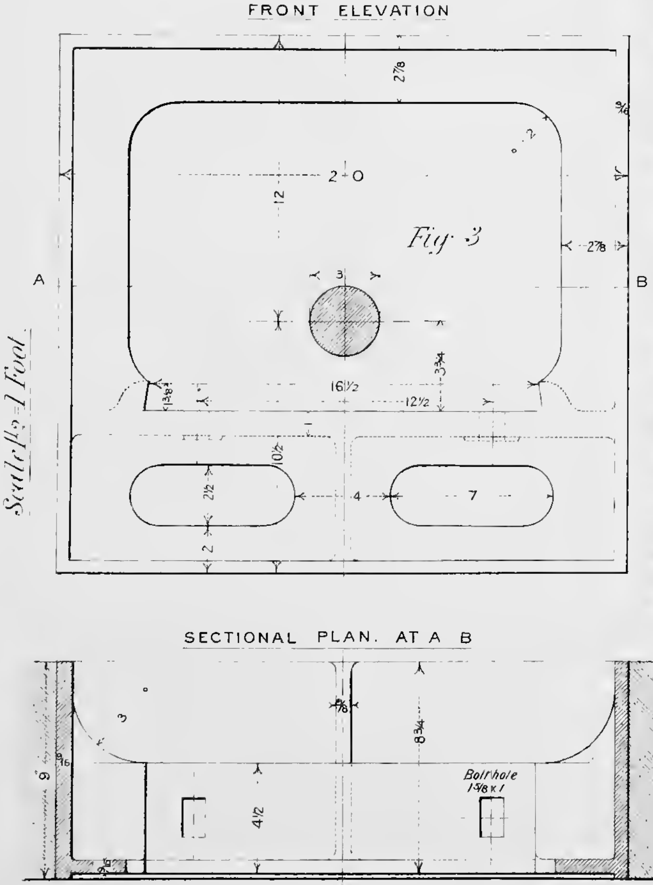
The distance S between the centres of the bearings for ordinary shafting is given by the formula.—*(Moleswerth.)*

$$S = 5\sqrt[3]{d^2}; \ S \text{ in feet and } d \text{ in inches.}$$

HANGER FOR 2½″ SHAFT.



WALL BOX FOR 3″ SHAFT.



WALL BRACKET FOR 3″ SHAFT.

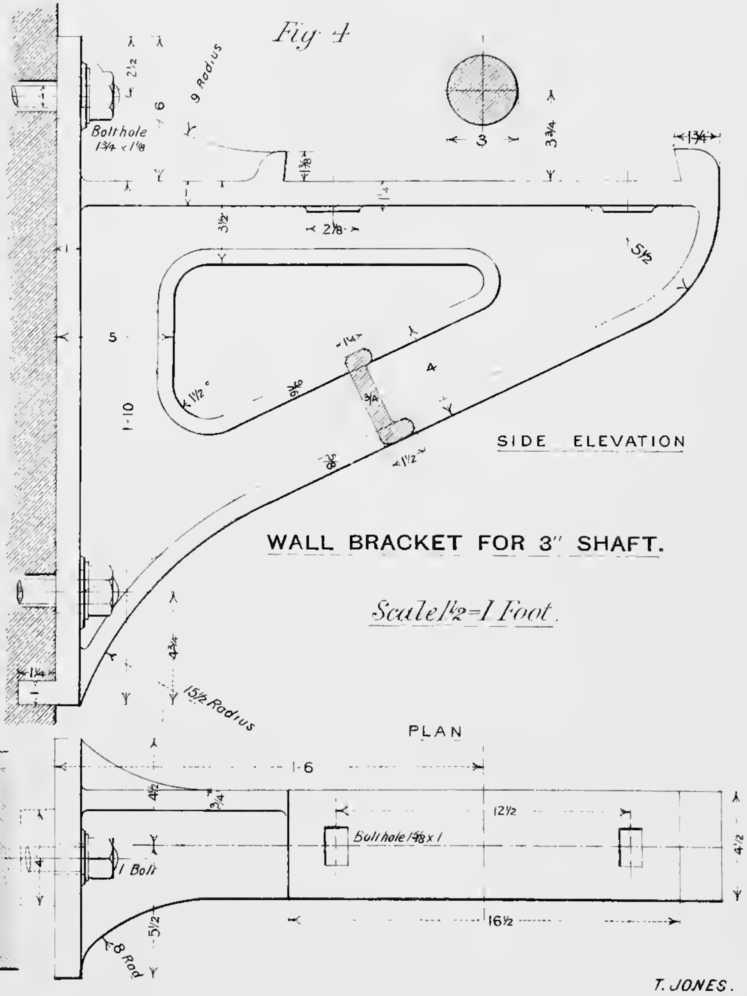


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Plate XV.—ADJUSTABLE HANGER AND SELLERS' COUPLING.

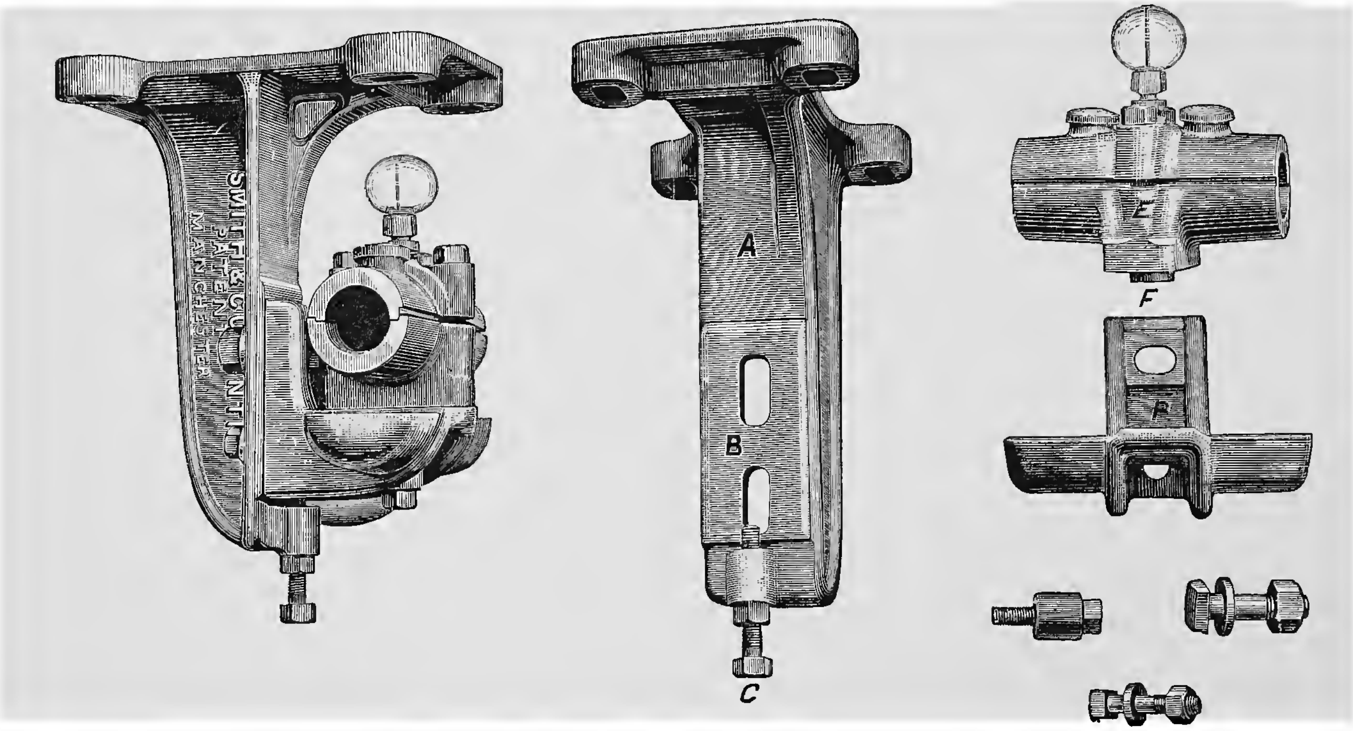
FIGS. 1 & 2 represent an adjustable hanger with a long cast iron bearing for the shaft. It is made of the ordinary J form, which facilitates the removal of the shaft when required. The cast iron frame E is fixed to a beam by means of two bolts, and is placed in such a position that the vertical face, to which the bracket F is bolted, is approximately parallel to the direction of the shaft.

The bearing consists of two parts, H and K, which are held together by two set screws. On the base of H a round pin is cast, which is turned to fit into a recess in the bracket F. This admits of the adjustment of the shaft in the direction of its axis. The bearing is held down to F by means of a screw N, passing through a cast iron ferrule, which packs out the head beyond the sides of F. The bracket F is fixed to E by the bolts L and M, in such a way that adjustment for height of the shaft can be made by the screw P. If the bearing is not exactly horizontal, the bracket F can be moved about the bolt M as a centre, the hole for the bolt L being slightly slotted to admit of this.

The lubrication is carried out efficiently. A needle lubricator is fixed to the centre of the cap K, and two tallow cups are cast on it. The glass vessel is filled with oil, and a wooden stopper, through which a needle passes, is fitted into it and then inverted and placed in the hole in the cap. The oil flows down the needle which vibrates when the shaft is in motion. If the supply of oil fails, overheating of the bearing is prevented, and lubrication performed by the tallow. The waste oil drops into the two cups cast on the sides of F.

The length of the bearing in these hangers is equal to about four times the diameter of the shaft.

THE FOLLOWING ILLUSTRATIONS AND DESCRIPTION HAVE BEEN SUPPLIED BY THE MAKERS.



The hanger consists of a frame Casting, A, having a planed vertical surface B, with set screw C, for adjustment of the bracket P; this bracket is secured to the vertical face by means of two bolts, the lower one acting as a pivot upon which it can swing laterally within a suitable limit, the hole through which the upper bolt passes being elongated to allow of this play. The pedestal E is seated on this bracket and held down securely by a bolt, in the centre, it has a turned projection, F, on its under surface, upon which it swings radially, thus affording a delicate adjustment to the shaft and ensuring perfect contact without the use of packing. The bearing surface in this hanger is four diameters in length, thus reducing the co-efficient of friction to a minimum, and being of cast iron is more durable and less expensive than in the ordinary hanger; a great saving of labour is also effected in the erection of shafting, the finest adjustments being so readily obtained. One oil cup and two tallow cups, one on each side, supply constant lubrication.

Fig. 3 shows a longitudinal and transverse section of a **Sellers' Coupling**. This coupling is now largely used, since it is easily adjusted, and the accurate fitting which is essential for other kinds of couplings, is not absolutely necessary.

The outer cylindrical shell A is turned on the inside to a double conical form. The two conical sleeves B slide on feather keys fitted on the shaft ends. The sleeves are cut through their length, which makes them slightly elastic.

They are brought together, and so press against the inner surface of A, by means of three bolts of square section, which fit in recesses cut into both A and B. The friction between the conical surfaces must be greater than the tangential force exerted upon them when the shaft is in motion.

EXERCISES.

1.—Draw three views of each of the main parts of the hanger, viz:—E, F, and H K. *Scale* $\frac{1}{2}$ *full size.* Note.—These will form three distinct drawings.

2.—Draw the three views of the hanger as given. Add a front elevation and also a plan of the bearing. *Scale* $\frac{3}{8}$″ *full size.*

3.—Draw the sections given in Fig. 3, adding an end elevation. *Scale* $\frac{3}{4}$ *full size.*

PLATE XV

ADJUSTABLE HANGER FOR 2½″ SHAFT.

SECTIONAL FRONT ELEVATION

SIDE ELEVATION

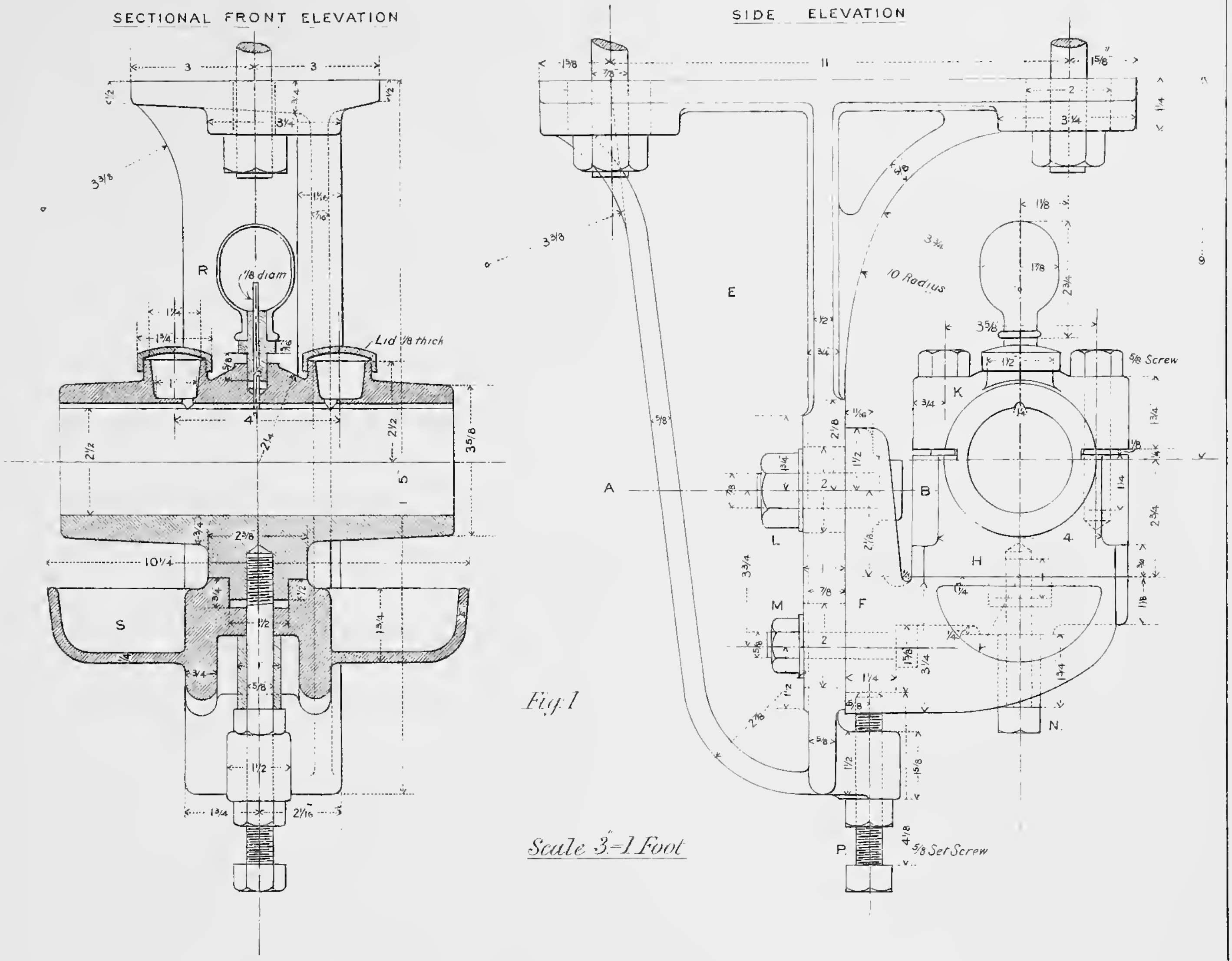


Fig. 1

Scale 3″=1 Foot

SECTIONAL PLAN A. B.
WITH CAP REMOVED

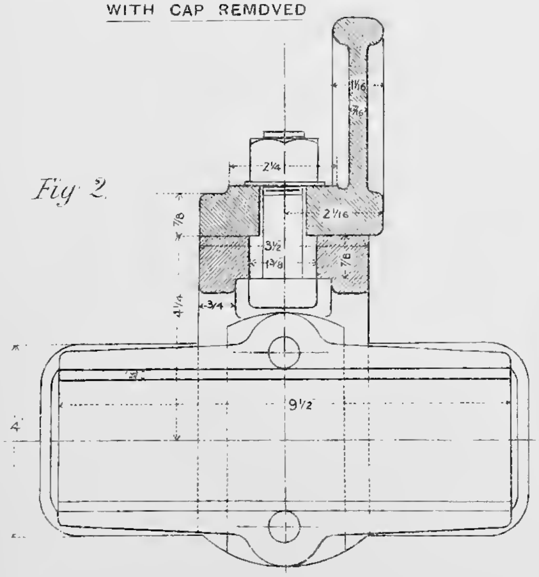
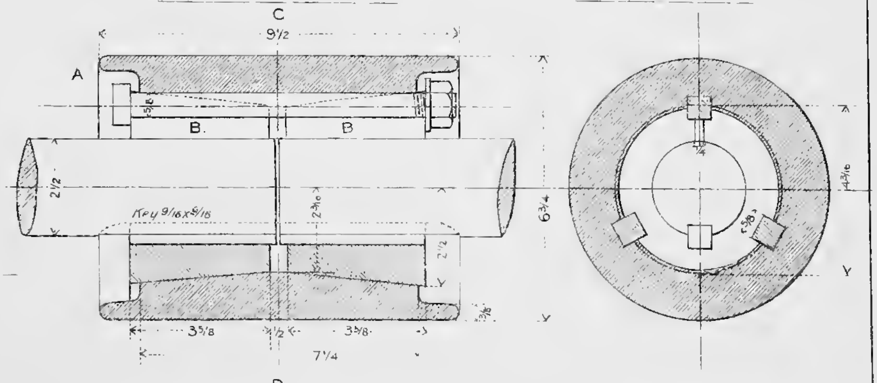


Fig. 2.

SELLERS' SHAFT COUPLING.

SECTIONAL ELEVATION

SECTION AT C. D.



Scale ⅕ full size

Fig. 3.

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Plate XVI.—BEARING AND STANDARD FOR SHAFTS.

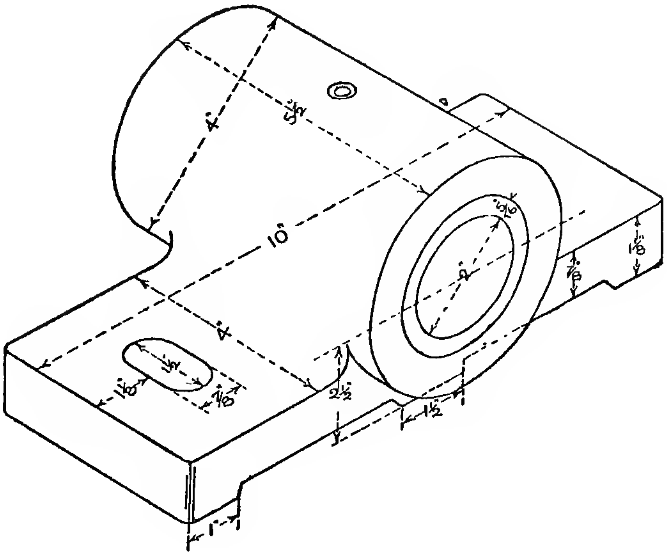
FIG. 1 gives two views of a cast-iron bearing for the crank shaft of a small pumping engine for a torpedo boat. The bearing is supported by two steel pillars, and is held in position by steel cotters. The steel pillars are held to the base plate of the engine by nuts screwed on the ends. The inverted cylinders are attached to the top end of the pillars in the same manner. It may be noted that the cap is held down by stud bolts, the central web preventing the use of ordinary bolts.

Fig. 2. This standard is used to carry a 12″ pedestal, for the first motion shaft of a large double acting pump, driven by a water wheel. It is made of box section, and is a good example of a large hollow casting. The flat sides are strengthened by the brackets shown in the sectional elevation. The pedestal is held in position by **T** headed bolts, which are passed down through the rectangular holes shown in the plan. The standard is secured to the bed of the pump by six bolts.

EXERCISES.

1.—Draw the three views of Fig. 1 as given, and add an end elevation. *Scale 9″ = 1 foot.*

2.—Draw the standard Fig. 2 as given, and add an end elevation. *Scale $\frac{1}{10}$ full size.*



3.—Draw front and end elevations, and also a plan of the *brass bushed* cast-iron filbore, shown in the accompanying isometric sketch. *Scale 9″ = 1 foot.*

CAST IRON BEARING FOR SHAFT.

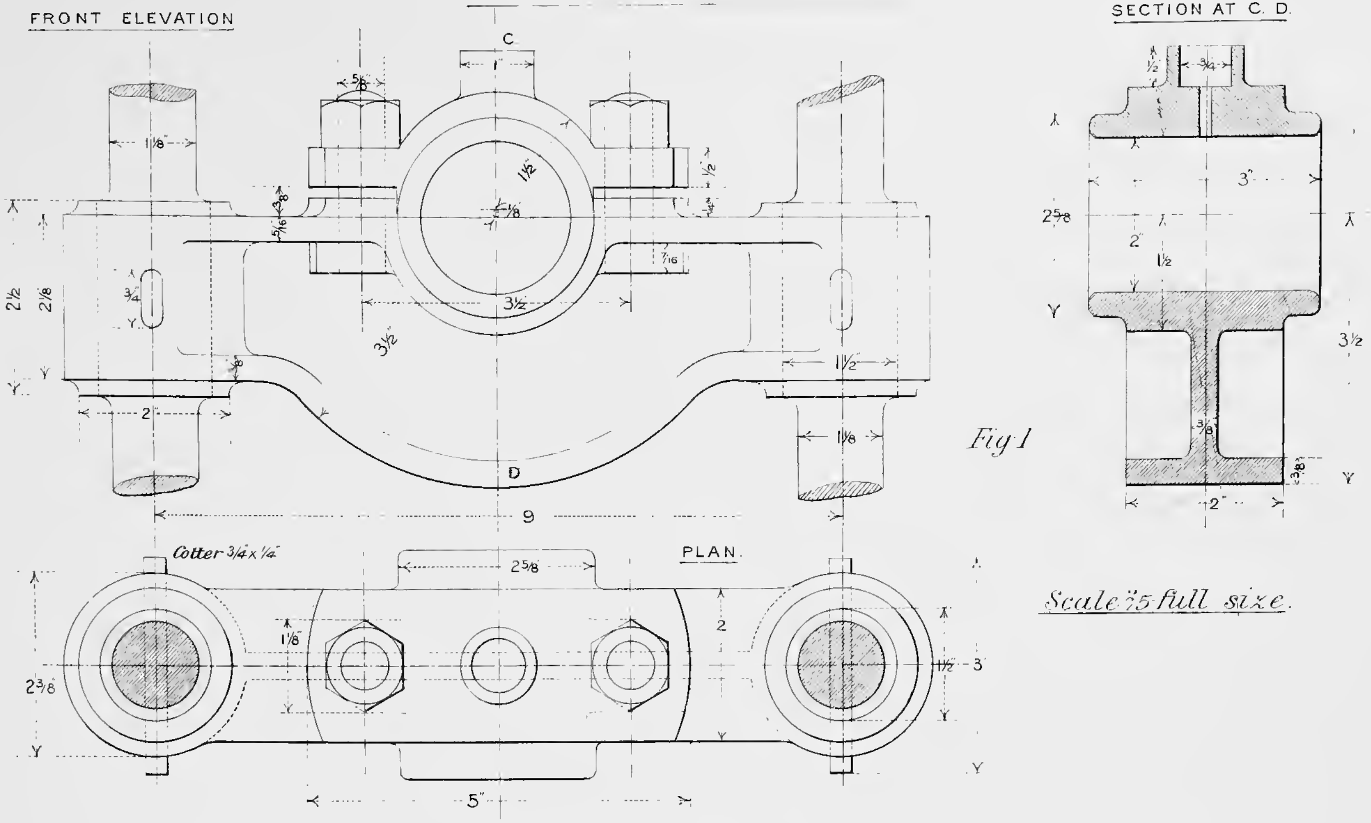


Fig 1

Scale 2/5 full size.

CAST IRON STANDARD FOR PEDESTAL.

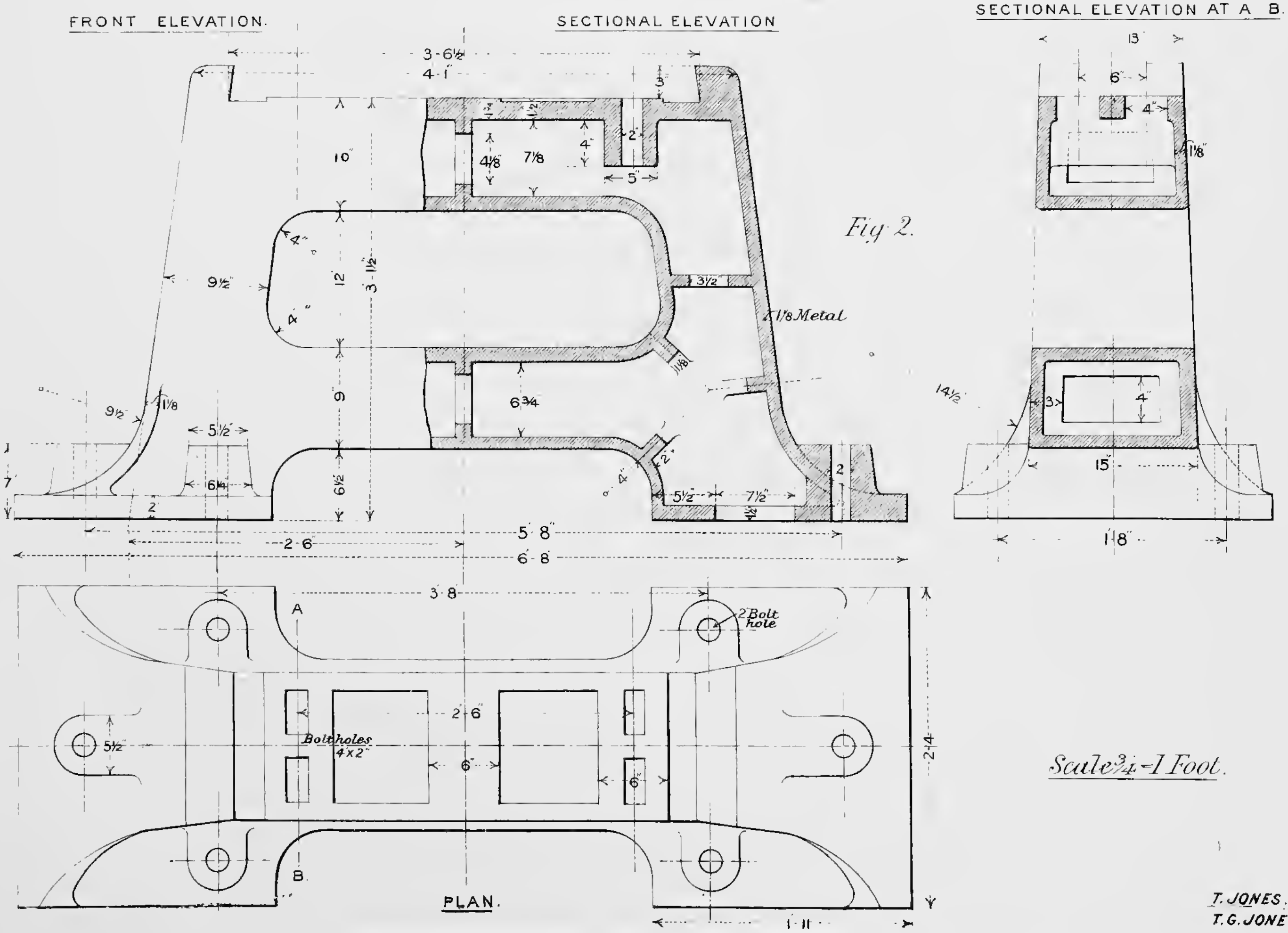


Fig 2.

Scale 3/4 = 1 Foot.

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Plate XVII.—CAST-IRON BELT PULLEYS.

PULLEYS are used for transmitting motion from a shaft to another one which is parallel to it. The connection is made either by belts or ropes. The material of the belt is either leather, india rubber and cloth, or gutta percha; and that of the rope, cotton or hemp. The belt is made endless, and stretched tightly over the pulleys; the driving being effected by the friction between the belt and the rim of the pulley. A pulley consists of three principal parts: the rim, the arms, and the boss, which are cast in one piece. By means of the boss the pulley is secured to the shaft. The arms, which are made taper, radiate from the boss and connect the rim to it. The width of the arms, at the rim, is two-thirds the width at the boss.

Figs. 1 and 2 are drawings of a pair of cast iron belt pulleys, Fig. 1 having curved arms, and Fig. 2 straight arms. The arm is elliptical in section; the axes of the ellipse are usually in the ratio of 2 : 1. Fig. 3 shows a method of drawing this ellipse approximately by arcs of circles. The rim is made convex in form, the radius of the curve being about $3w$, where w = width of the pulley. This form of rim keeps the belt in the centre, since every portion of it tends to move to the greatest diameter of the pulley.

Fig. 4 gives an example of a cast-iron cone or speed pulley, as used for driving machines or tools, where a *variable* velocity is required to be transmitted, from a shaft moving at a *constant* velocity.

The velocity ratio of shafts, driven by pulleys, is inversely proportional to the diameters of the pulleys keyed on them, assuming no slip to occur. Suppose a pulley n'' diameter keyed to a shaft making A revolutions per minute; and a pulley m'' diameter keyed to a shaft making B revolutions per minute; then $n : \mathsf{B} :: m : \mathsf{A} \therefore n\,\mathsf{A} = m\,\mathsf{B}$. $\therefore$ it follows that the diameter of pulley × revolutions of shaft is constant, for any pair of shafts connected by belts and pulleys.

HORSE POWER OF LEATHER BELTS.

When a belt is in motion the tension in one side is greater than the other. The power which can be transmitted, depends upon the velocity of the belt, and the *effective* tension, which is the *difference* in tension in the tight and slack sides. The ratio of these tensions varies with the arc embraced by the belt, and the co-efficient of friction between the belt and pulley. Prof. Unwin gives a table of these ratios $\frac{\mathsf{T}_1}{\mathsf{T}}$, from which the following values are taken; co-efficient of friction, $= \cdot 4$. T_1 = tension in the tight side; T = tension in the slack side:—

(1) $\frac{\mathsf{T}_1}{\mathsf{T}} = 2{\cdot}4 = \frac{24}{10}$ for an arc of 126° – pulleys 10 ft. and 1 ft. – 10 ft. centres.
(2) ,, $= 3 = \frac{30}{10}$,, ,, 156° – ,, 5 ft. and 1 ft. – 10 ft. ,,
(3) ,, $= 3{\cdot}5 = \frac{35}{10}$,, ,, 180° – ,, 4 ft. and 4 ft. – 10 ft. ,,

The maximum safe working stress in a leather belt, through the laced joint, is 360 lbs. per square inch = 90 lbs. per inch of width for a belt $\frac{1}{4}''$ thick. In each of the above examples a belt 10″ wide is assumed, $\therefore$ the total safe working stress $= 90 \times 10 = 900$ lbs. The effective tension $\mathbf{t}$ is found as shown below.

$\mathsf{H} = \frac{\mathbf{t} \times \mathbf{v}}{33000}$, where $\mathbf{v}$ = velocity of belt in feet per minute, and H = the horse power.

In example 1 – $\mathbf{t} = \frac{900 \times 14}{24}$; $\mathbf{v} = 600\,\pi$ for 60 revolutions of 10 feet pulley, $\mathsf{H} = 30$.

Example 2 – $\mathbf{t} = \frac{900 \times 2}{3}$; $\mathbf{v} = 600\,\pi$ for 120 revolutions of 5 feet pulley, $\mathsf{H} = 34\frac{2}{7}$.

Example 3 – $\mathbf{t} = \frac{900 \times 25}{35}$; $\mathbf{v} = 600\,\pi$ for 150 revolutions of 4 feet pulley, $\mathsf{H} = 36\,\frac{36}{49}$.

A rough approximate rule, which is sometimes used, is given below. It is based upon the assumption that a belt, running at 1000 feet per minute, will transmit 2 horse power for each inch of width:—

$$\mathsf{H} = \cdot 006\ \mathrm{D}\ \mathbf{w}\ \mathrm{R},$$

where D = diameter of pulley in feet; $\mathbf{w}$ = width of belt in inches; R = number of revolutions per minute.

This rule gives for the above examples, which are all for the same width and speed of belt, $\mathsf{H} = 36$. This is the power determined above for pulleys of the same diameter.

EXERCISES.

1.—Draw the two cast-iron pulleys as given in Figs. 1 and 2. *Scale* 3″ = 1 *foot.* Show a full sized section of an arm.

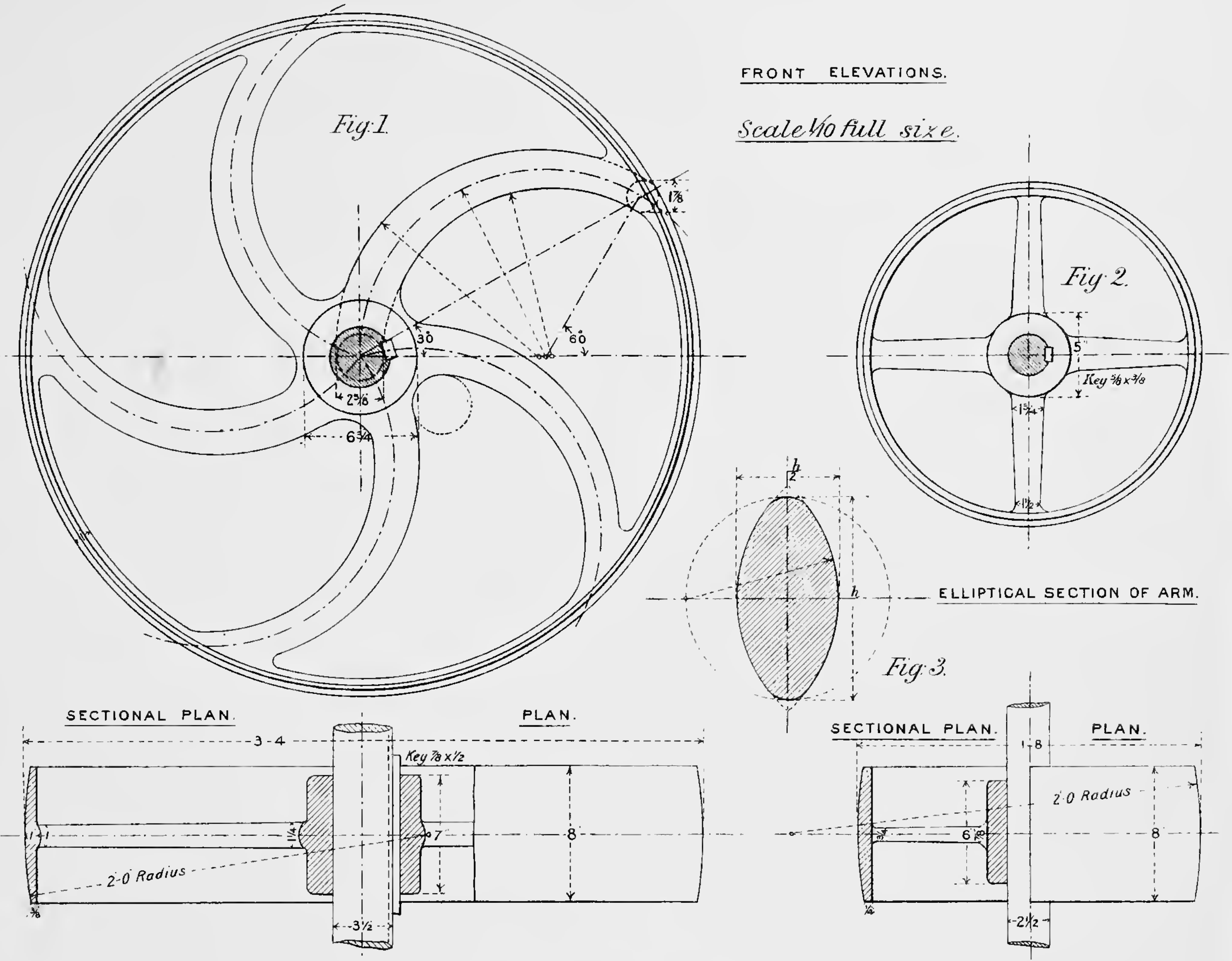
2.—Draw the sectional and end elevations of the cone pulley given in Fig. 4, adding a plan and an end elevation looking inside the pulley. *Scale* $\frac{3}{4}$ *full size.*

3.—Determine the maximum and minimum velocities of the cone pulley, supposing it to be driven from a countershaft running at 100 revolutions per minute, by a pulley of the same dimensions.

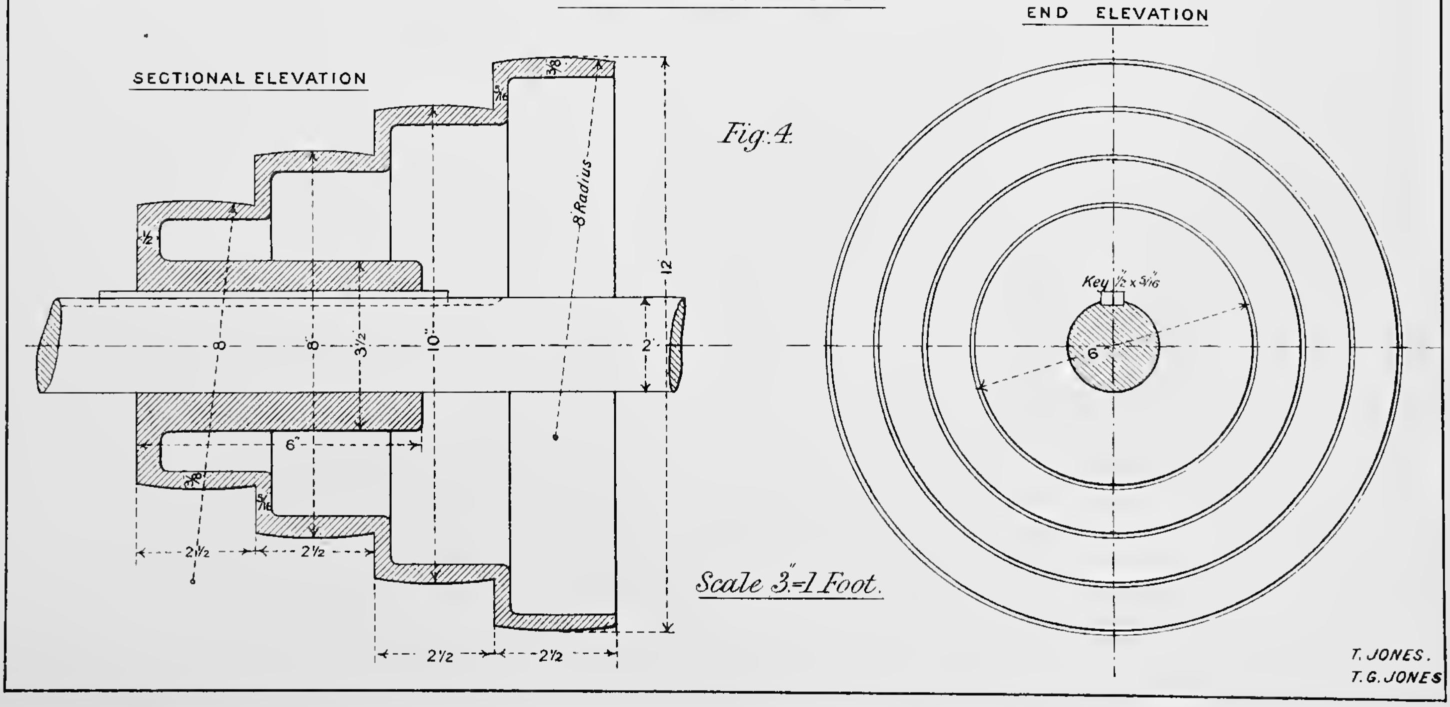
4.—Determine also the variable horse power of the belt, which is $2\frac{1}{4}''$ wide, under the same conditions.

5.—Taking the pulley Fig. 1, running at 150 revolutions per minute, find the horse power of the belt, which is 7″ wide.

CAST IRON BELT PULLEYS.



CONE OR SPEED PULLEY.



Scale 3" = 1 Foot.

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Plate XVIII.—ROPE PULLEY AND FLY WHEEL.

COTTON ropes are now very extensively used for main driving in mills. This method of transmitting power is smooth, silent and very efficient. The engine fly wheel is grooved to receive a number of ropes, sufficient for distributing the whole power of the engine.

The main shaft to each room is fitted with a pulley, provided with grooves equal in number to the ropes required to drive the room. In rope driving, as well as in belt driving, the lower side of the rope or belt should be the tight side, since the slack or sag of the belt on the upper side, causes it to wrap further round the pulley. This makes the driving more efficient for the same tension.—*See notes to Plate XVII.*

The driven shaft should never be placed vertically over the engine crank shaft; the minimum horizontal distance between them being about 20 feet. The diameter of rope generally used is $1\frac{3}{4}''$, and the smallest diameter of pulley should not be less than 30 times the diameter of the rope, to avoid undue bending. The groove should be shaped so that the rope can leave it easily without tearing the fibres, and still have sufficient grip for driving. When a rope is running, it usually rotates slowly on its axis. This prevents it taking a permanent pear shape, due to the pressure in the groove.

HORSE POWER OF ROPES.

A rope $1\frac{3}{4}''$ diameter, running at 1000 feet per minute, will transmit 10 horse power. The following formula gives this value approximately :—

$$H = \cdot 03DR.$$

H = horse power; D = diameter of pulley in feet; R = revolutions of pulley per minute.

The speed of the ropes varies from 3000 to 5000 feet per minute.

Fig. 1 gives two views of a cast iron rope pulley to carry 4 ropes of $1\frac{1}{2}''$ diameter. Fig. 2 shows an enlarged section of the rim; the angle between the sides of the groove is 45°.

Fig. 2 shows two views of a cast iron fly wheel for a small engine. The boss is divided into three parts, to allow for the contraction of the arms in cooling after casting. A steel ring is afterwards shrunk on each side of the boss to draw the parts together.

The boss is cored out to lighten it, and also to save labour in boring and fitting it to the shaft, to which it is keyed.

Fly wheels are used to store up energy. In the case of an engine, the power transmitted from the piston varies considerably. The work to be done is usually constant for a given time, and the *mean* work done on the piston represents the work required. The excess *above* this mean is absorbed by the fly wheel, which gives it up again when the work done by the piston is *below* this mean.

In this way the fly wheel carries the crank over the dead centres, when the turning effort on the crank shaft is nil.

EXERCISES.

1.—Draw the two views of the rope pulley as shown, and add a side elevation. *Scale 2″ = 1 foot.*

2.—Draw the section of the rim shown in Fig. 2, *full size.*

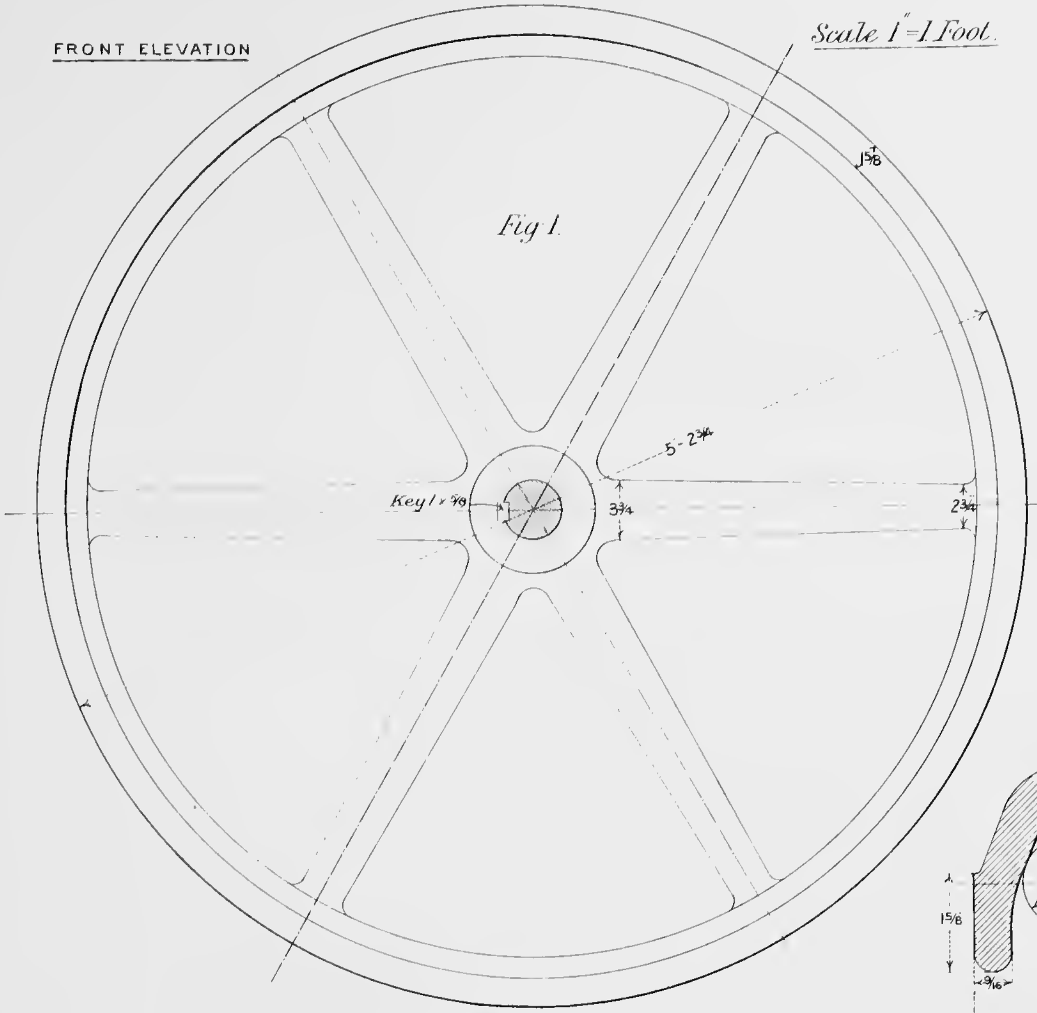
3.—Draw the two views of the fly wheel given in Fig. 3, and add a plan. *Scale 2″ = 1 foot.*

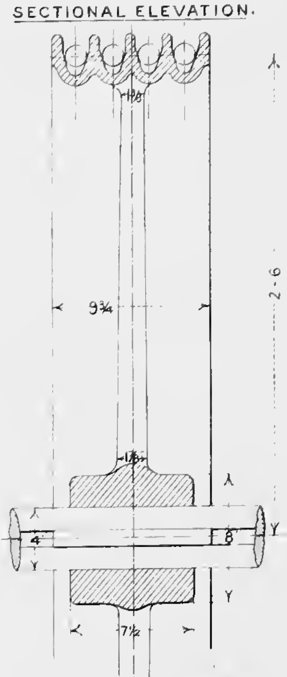
4.—Determine the horse power of one of the ropes in the given rope pulley, which makes 200 revolutions per minute. Assume the ratio of horse power to be as the area of the section of the rope.

5—Determine the tension in the rope per square inch of section.

ROPE PULLEY 5 FEET DIAMETER.

Scale 1" = 1 Foot.





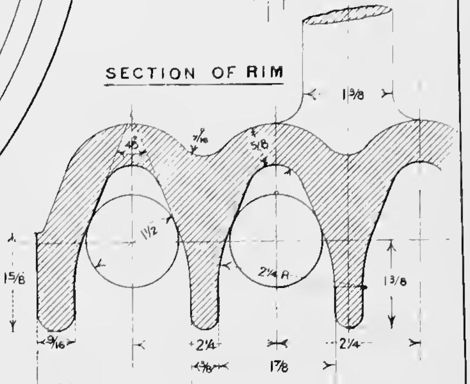
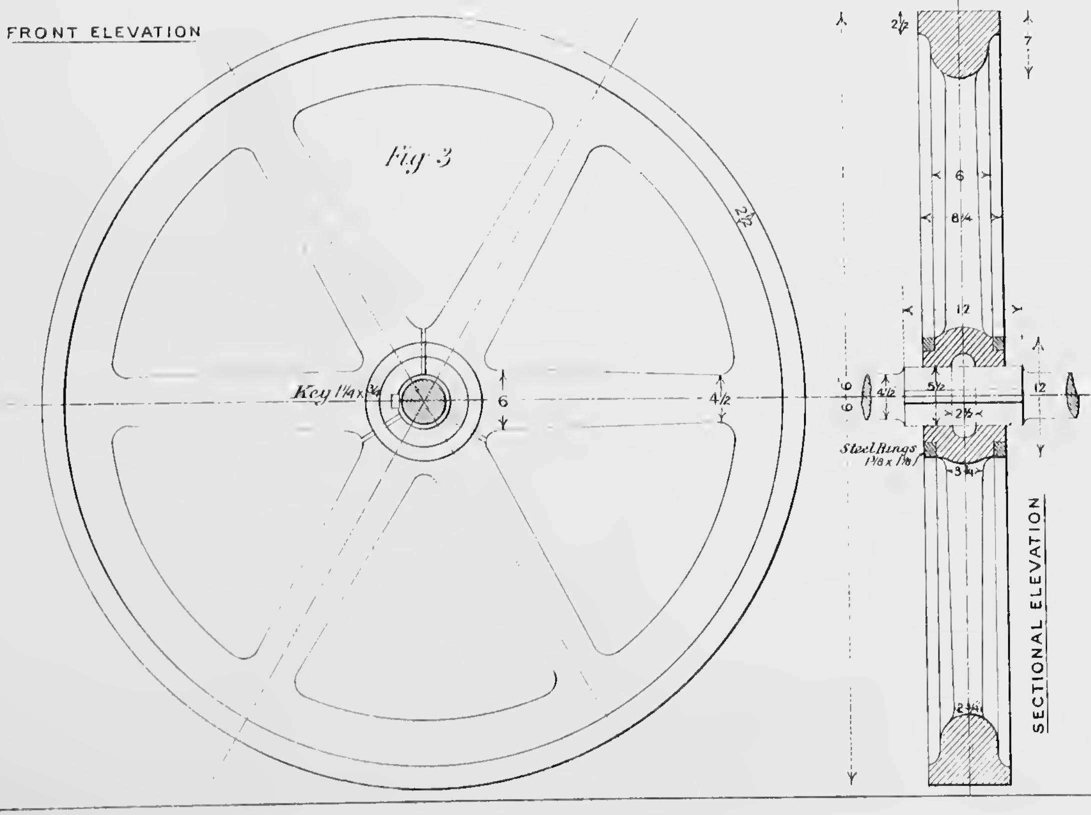


Fig 2.



FLY WHEEL.

6-6 DIAM^{R}.

Scale 5/8" = 1 Foot

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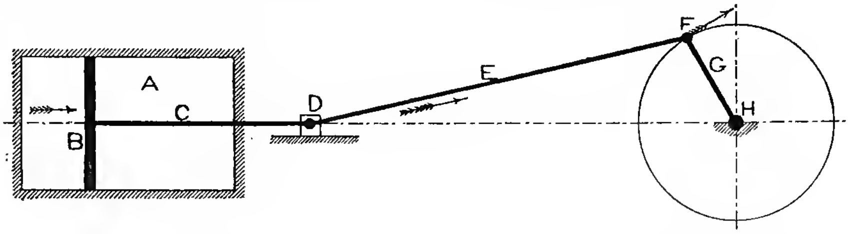
Plate XIX.—ENGINE CRANKS.

THE crank of an engine is employed for converting the reciprocating motion of the piston into the circular motion of the crank shaft. It is a simple lever, one end being keyed upon the end of the crank shaft, and the other provided with a cylindrical projection called the crank pin, placed parallel to the shaft. The motion of the piston is transmitted to the crank by means of an intermediate piece, the connecting rod. The distance between the centres of the crank shaft and pin is the throw of the crank, and equals half the stroke of the piston.



A—Engine cylinder.
B—Piston.
C—Piston rod.
D—Crosshead.
E—Connecting rod.
F—Crank pin.
G—Crank.
H—Crank shaft.

The above line diagram shows the relative positions of the various parts of an engine.

Owing to the regulating influence of the fly wheel, the crank revolves uniformly, and the piston therefore moves at a variable velocity. The crank pin describes a circle, whilst the piston makes two complete strokes.

$$\therefore \frac{\text{mean velocity of crank pin}}{\text{mean velocity of piston}} = \frac{\pi s}{2s} = \frac{\pi}{2} = 1{\cdot}5708. \qquad s = \text{stroke}.$$

The mean pressure on the crank pin is $\frac{2}{\pi}$ times the mean effective pressure on the piston. The connecting rod exerts a pressure on the crank pin in the direction of its length. The component of this pressure, at right angles to the crank, is the tangential pressure or turning effort on the crank pin; and when multiplied by the length of the crank, gives the turning moment on the crank shaft.

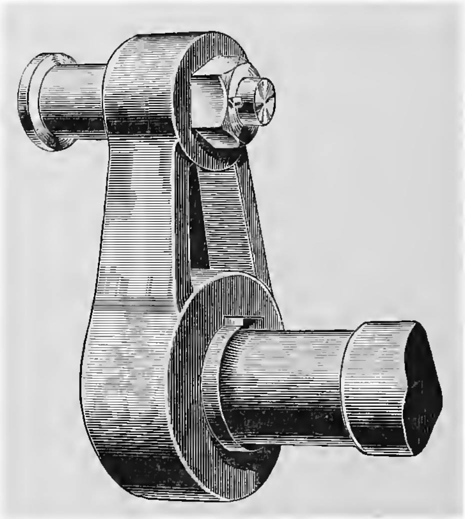


Fig. 1 and the accompanying illustration show the ordinary overhung cast iron crank. It consists of an arm **N**, with a boss on each end, through which pass the end **M** of the shaft, and the crank pin **P** respectively.

The crank is shrunk on, and keyed to the end of the shaft. The end of the pin is conical, fits into the hole in the crank, and is secured by a nut and taper pin.

Since the crank overhangs, the bearing should be brought close to the face of the crank, in order to minimise the twisting on the crank arm. The arm is of rectangular section, stiffened by two webs cast on the sides.

Sometimes a single web is placed in the centre of the arm, but this is not so good, since it only slightly assists in resisting the bending moment to which the arm is subjected.

Fig. 2 shows one form of a forged crank; the two bosses are connected by an arm **N**, of rectangular section. It is secured to the shaft **M** by a key, as in the previous example. The crank pin **P** is fixed by a steel cotter, which passes through the boss and the shank of the pin. The shank is cylindrical, and the pressure due to the draw of the cotter is taken up by the collar.

EXERCISES.

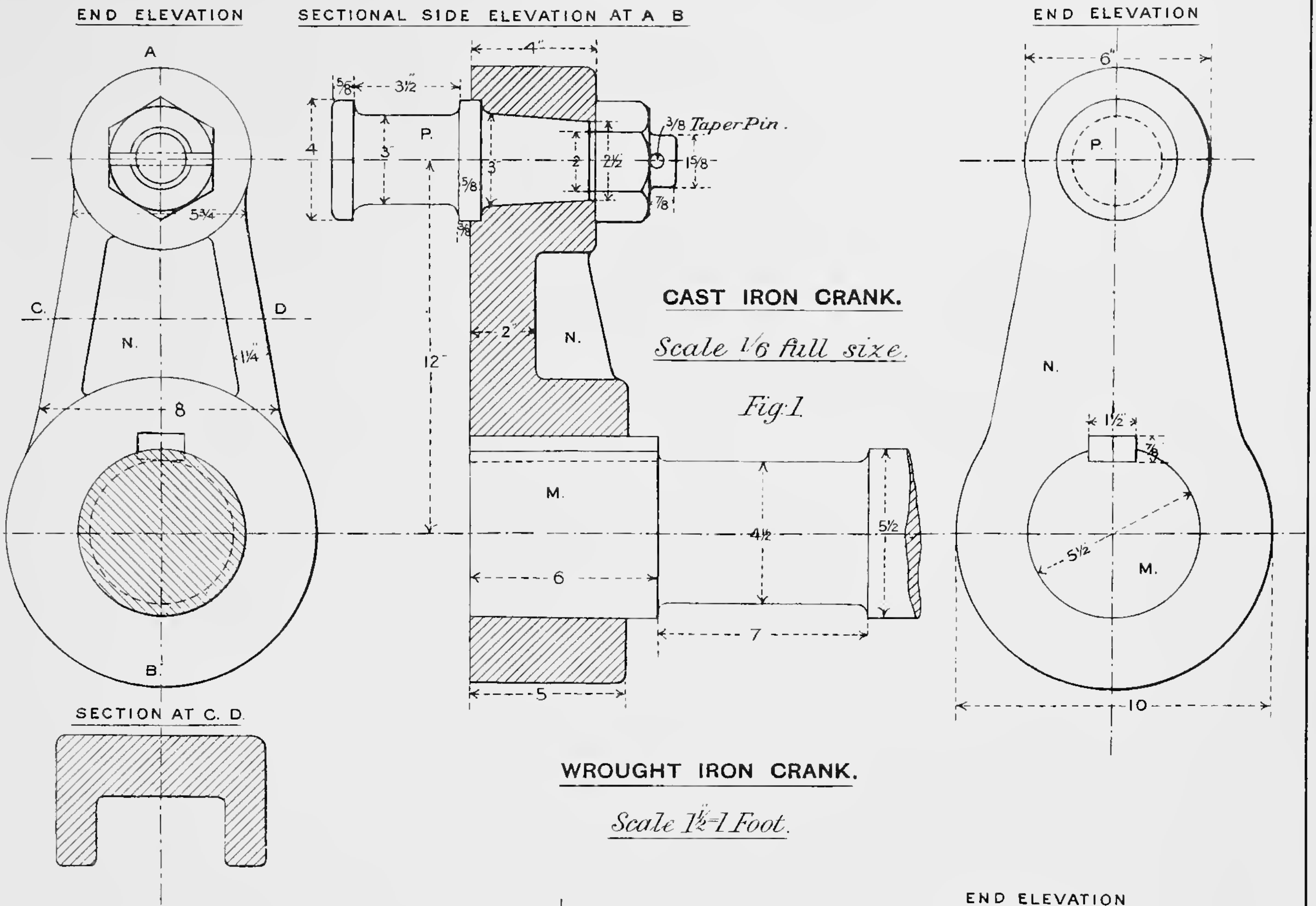
1.—Draw the views of the cast iron crank as given in Fig. 1, and add a side elevation and plan. *Scale 4″ = 1 foot.*

2.—Draw the wrought iron crank as given in Fig. 2, and add a longitudinal section. *Scale $\frac{1}{6}$ full size.*

3.—Given the force acting on the piston; determine graphically the reaction on the slide bars, the force along the connecting rod, and the turning effort on the crank pin.

PLATE XIX

ENGINE CRANKS.



CAST IRON CRANK.

Scale 1/6 full size.

Fig. 1.

WROUGHT IRON CRANK.

Scale 1½"=1 Foot.

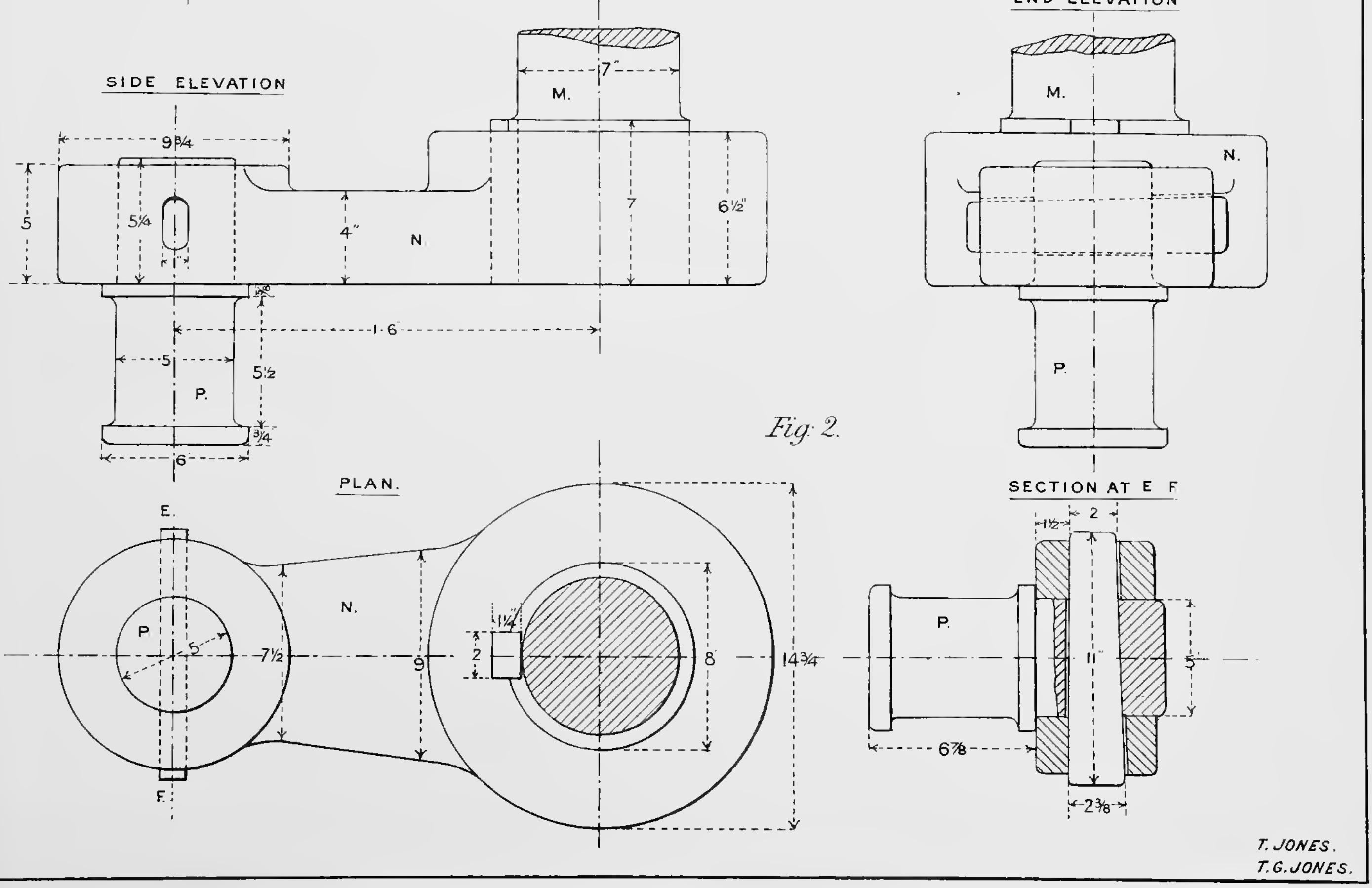


Fig. 2.

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Plate XX.—ENGINE CRANKS AND CRANK SHAFTS.

FIG. 1 shows a double built up crank, as used for marine engines. It is supported on both sides of the pin, and thus the twisting on the arm is reduced. All the parts are made of compressed steel. The pin M, and the shaft L L, are hollow; this is the best section to resist twisting and bending for a given weight of metal. The pin M is turned and finished, and the arms N N then shrunk upon it, and secured by steel keys. The shaft ends, which are secured to the arms in the same manner, have flange couplings forged to them, which serve for connecting to other cranks or shafts. The holes in the arms are made $\frac{1}{1000}$ of the diameter less than the parts to which they fit.

Fig. 2 shows two views of a steel crank shaft for a locomotive engine with inside cylinders. The two cranks, which are at right angles, are forged in one piece with the shaft. The driving wheels are shrunk on the ends of the shaft, and the bearings placed between the cranks and the wheels. The eccentrics, which actuate the slide valves, are placed between the cranks. See Plate XXI. for drawing of a locomotive eccentric. The arms taper slightly towards the pin, and their ends are curved to a radius of 12″.

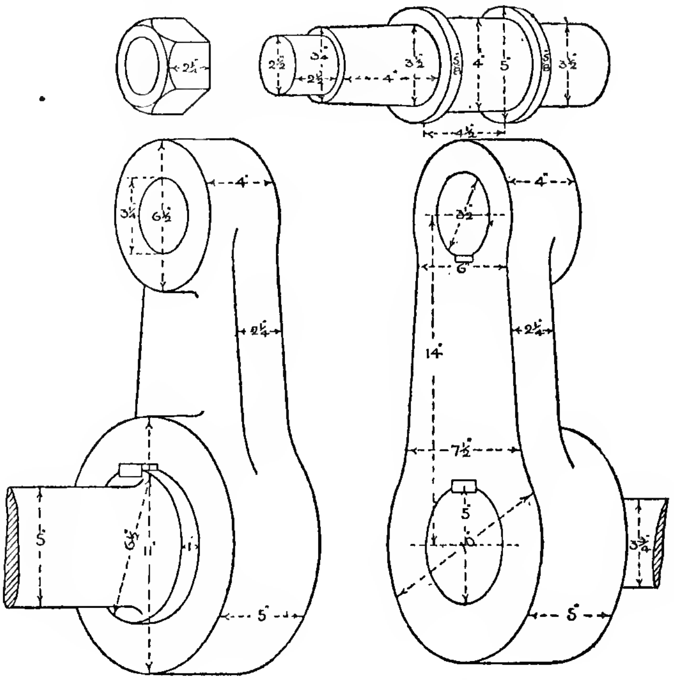
Fig. 3. This type of crank, as its name implies, is formed of a disc of cast-iron, which is keyed to the end of the shaft S in the usual way. The portion of the disc on the opposite side to the crank pin is made heavier, to balance the weight of the pin and connecting rod. The steel crank pin is held in its place by a steel key.

EXERCISES.

1.—Draw the marine engine crank shaft to the dimensions given in Fig. 1, adding a plan. *Scale* 1″ = 1 *foot.*

2.—Draw the locomotive crank shaft as given, and add a plan. *Scale* 1½″ = 1 *foot.*

3.—Draw the three views of the disc crank as shown in Fig. 3, and add a plan. *Scale* 2″ = 1 *foot.*



4.—The accompanying sketch gives the dimensions of a double crank. Draw the side and end elevations, and also a plan, when the parts are fitted together. *Scale* 4″ = 1 *foot.*

The student must determine the proper dimensions for the keys required.

PLATE XX.

ENGINE CRANKS AND CRANK SHAFTS.

MARINE CRANK SHAFT.

Scale 1/20 full size.

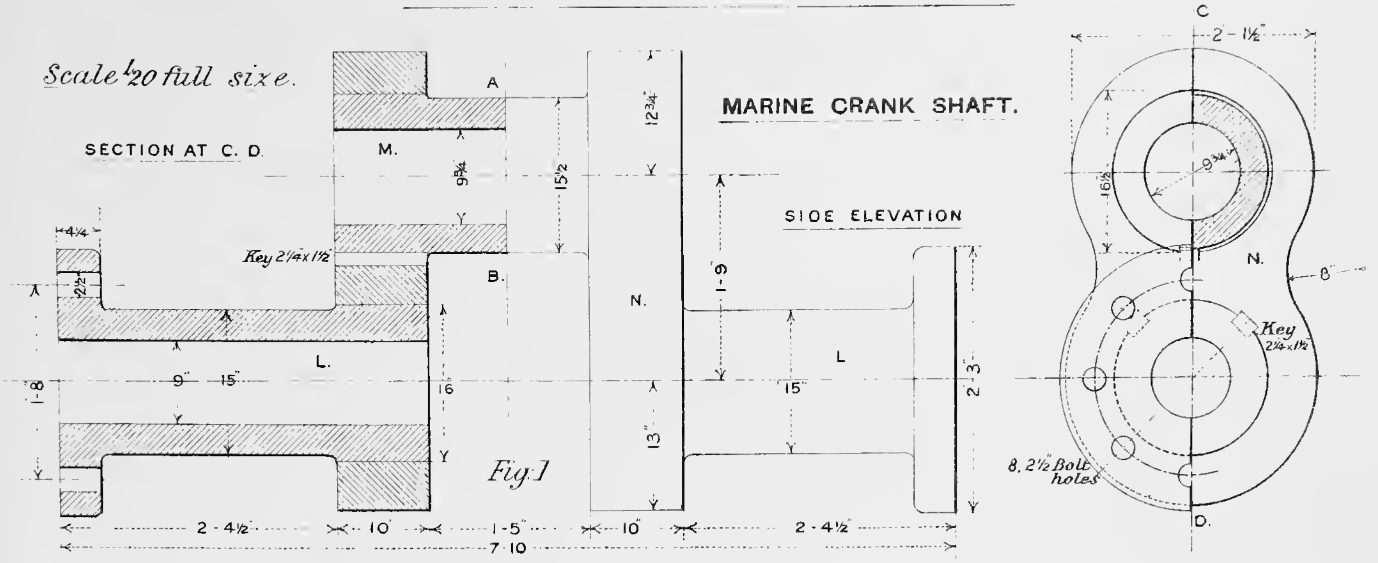


Fig. 1

LOCOMOTIVE CRANK SHAFT.

Scale 1" = 1 Foot

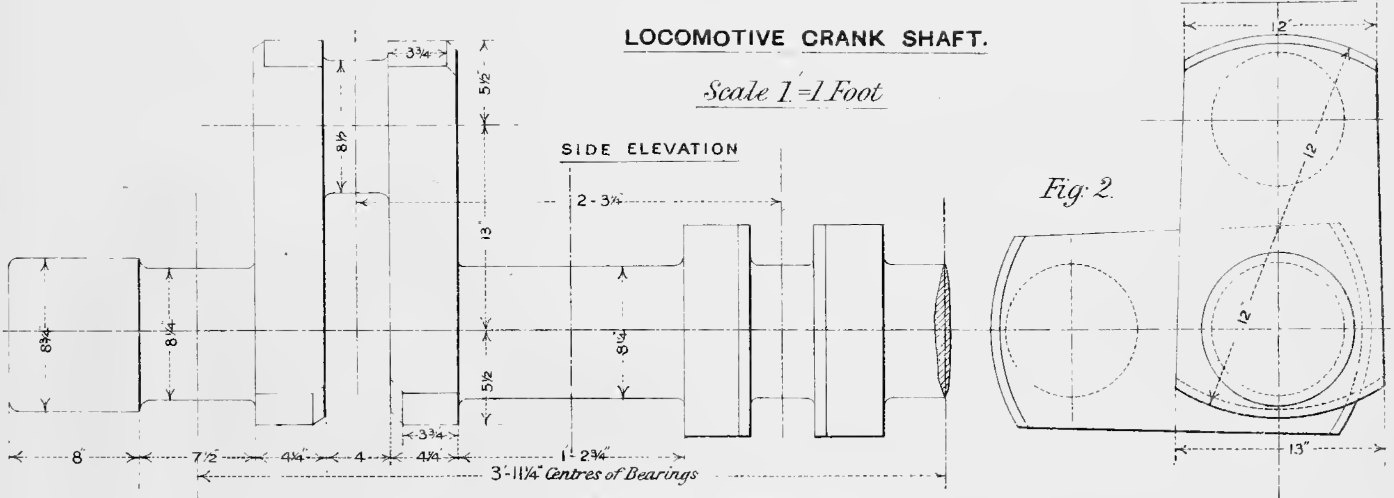


Fig. 2

CAST IRON DISC CRANK.

Scale 1/10 full size

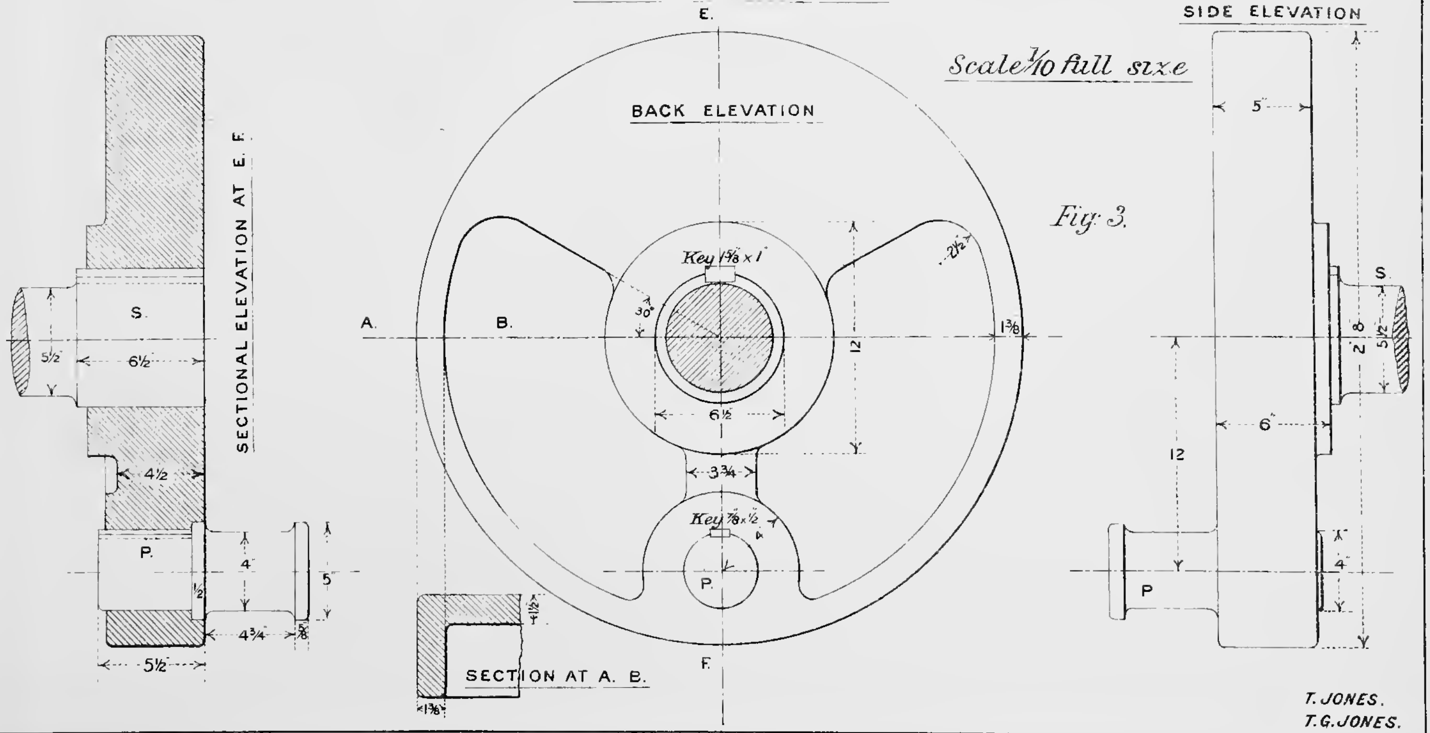


Fig. 3.

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Plate XXI.—ECCENTRIC OF LOCOMOTIVE, &c.

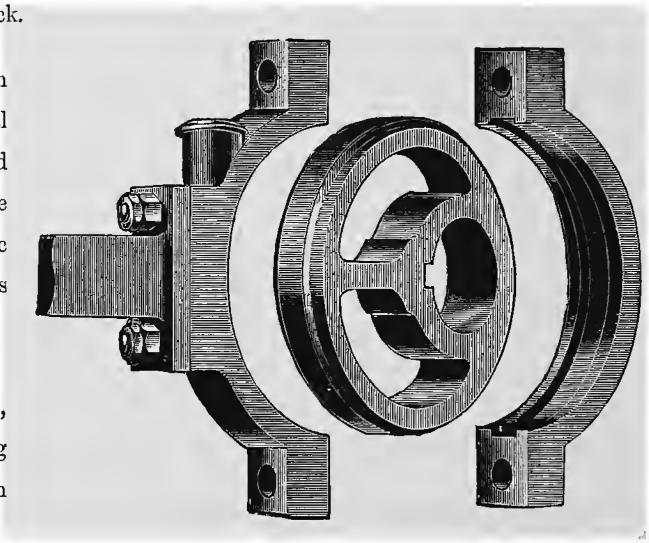
AN eccentric is a special form of crank, where the radius of the crank pin is greater than the sum of the radii of the crank and the shaft. It is chiefly used to give motion to the slide valve of an engine, or to work the ram of a small pump, where the motion is taken from an engine crank shaft, and the stroke of the pump a short one.

Fig. 1 represents an eccentric for working the slide valve of a locomotive engine. The eccentric sheave is made in two parts, **A** and **B**, jointed in a plane containing the axis of the shaft, at right angles to a plane passing through this axis, and the centre of the sheave. The smaller piece **A** is made of wrought iron, and the larger one **B**, of close grained cast iron. They are held together by two cotter bolts, and the whole sheave is fixed to the crank shaft by a small key and two set screws, secured by lock nuts. The necessity for making the sheave in two parts will be understood on referring to the crank shaft, Fig. 2, Plate XX. The distance between the axes of the shaft and the sheave is the throw of the eccentric, and half the travel of the valve which it actuates.

The straps **C** and **D**, which embrace the sheave, are made of cast iron, and held together by the bolts **H H**.

The strap **C** is attached to the end of the eccentric rod **E**, by two stud bolts. An oil cup is cast to this strap, and the lubrication is effected by means of a syphon of cotton wick.

Fig. 2 and the accompanying illustration show an ordinary eccentric and strap as used in small horizontal engines. The sheave, which is cast in one piece, is keyed to the end of the crank shaft outside the bearing. The straps **B** and **C** are held together by two bolts, the eccentric rod **E** being attached to the strap **C**, as in the previous example.



EXERCISES.

1.—Draw the front elevation of the eccentric, Fig. 1, and add a plan and also a complete side elevation, looking on the end of the eccentric rod. Show also a side elevation of the sheave. *Scale 4″ = 1 foot.*

2.—Draw the elevation and plan of the eccentric and rod, Fig. 2, and add a side elevation looking on the end of the eccentric rod. *Scale $\frac{3}{8}$ full size.*

QUESTIONS.

1.—Show by means of a sketch, how the two parts of an eccentric sheave are joined together, when the sheave cannot be passed over the end of the shaft. Describe the sketch.

2.—When the eccentric strap, shown in Fig. 2, becomes loose by wear, how is it adjusted? What is the travel of the slide valve, the spindle of which is connected directly to the end of the eccentric rod?

3.—Give two methods of attaching an eccentric rod to the strap.

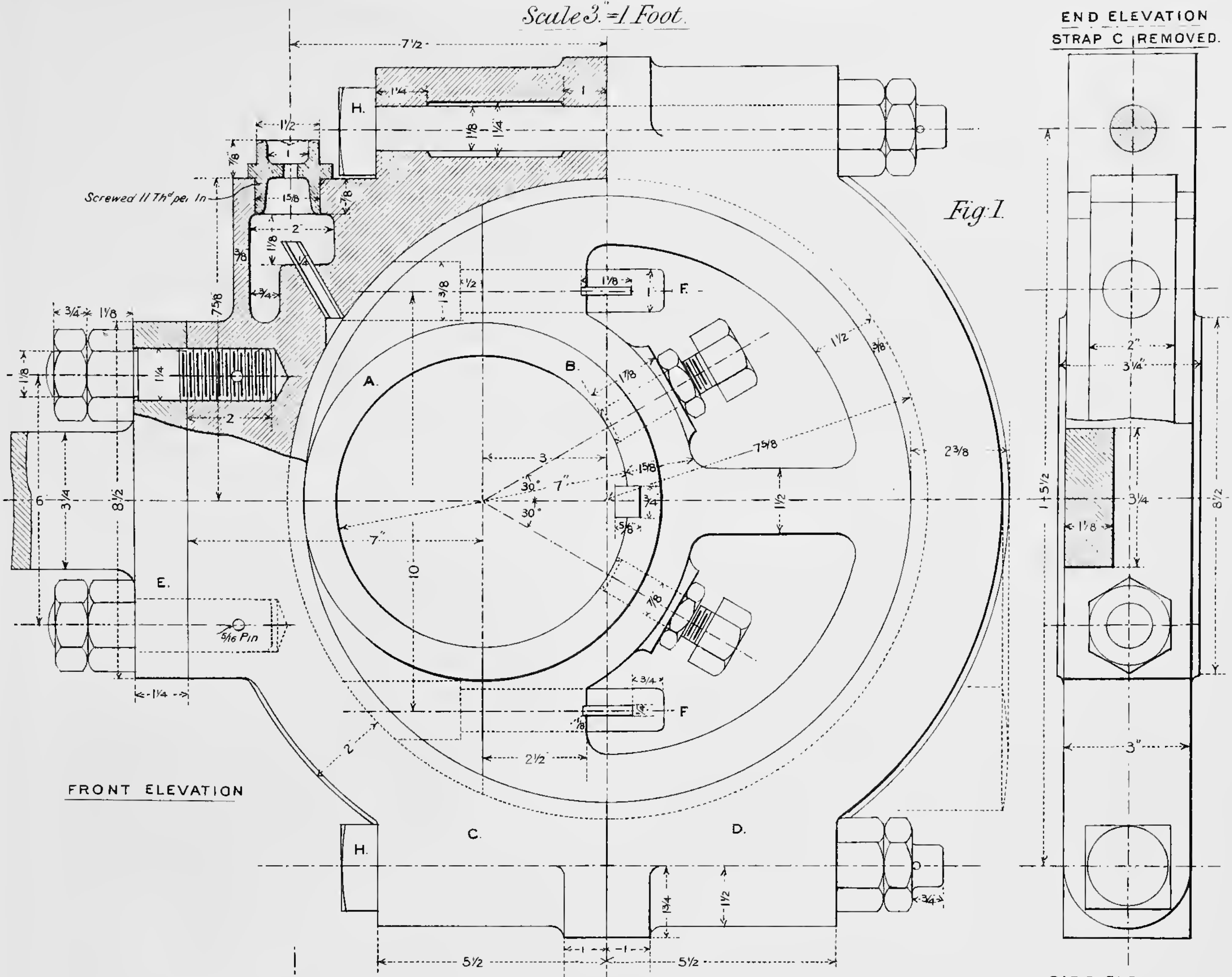
4.—Show by sketches how an eccentric strap is lined with brass.

5.—Distinguish between the use of an eccentric and rod, and a crank and connecting rod.

PLATE XXI

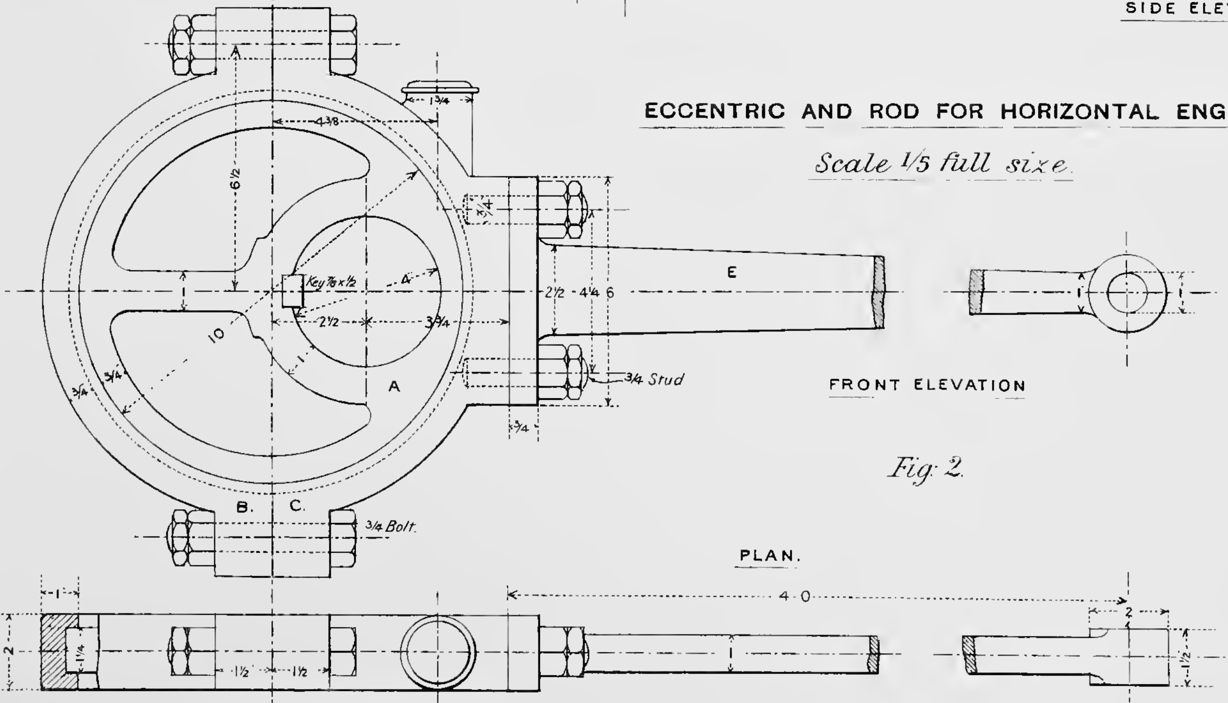
ECCENTRIC FOR LOCOMOTIVE ENGINE.

Scale 3" = 1 Foot.



ECCENTRIC AND ROD FOR HORIZONTAL ENGINE.

Scale 1/5 full size.



T. JONES.
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Plate XXII.—CONNECTING ROD ENDS.

THE connecting rod of an engine is the link which connects the crosshead to the crank pin. By its use, in conjunction with the crosshead and crank, the rectilinear motion of the piston is converted into the circular motion of the crank shaft. The length of the rod, from the centre of the crosshead pin to the centre of the crank pin, should, if possible, never be less than four times the length of the crank arm, since a short rod produces an excessive pressure on the slide bars.

The usual length of rod for land engines, is from five to seven times the crank arm. The two ends of the rod are accurately fitted with adjustable bearings, to take up the wear. The crosshead pin is smaller than the crank pin, because the former is in double shear, and the latter is supported at one end only, and is subjected to a bending moment. This is the reason for the difference in the construction of the two ends of the rod.

A connecting rod has not only to be stiff enough to resist the alternate thrust and pull to which it is subjected, but also to resist the tendency to bend due to its rapid oscillations. The section of the rod is usually circular, having its greatest diameter near the centre of its length, or else, gradually increasing in diameter from the crosshead to the crank pin end.

In a locomotive engine, the rod is rectangular in section, the longer side being in a plane at right angles to the axis of the crank pin.

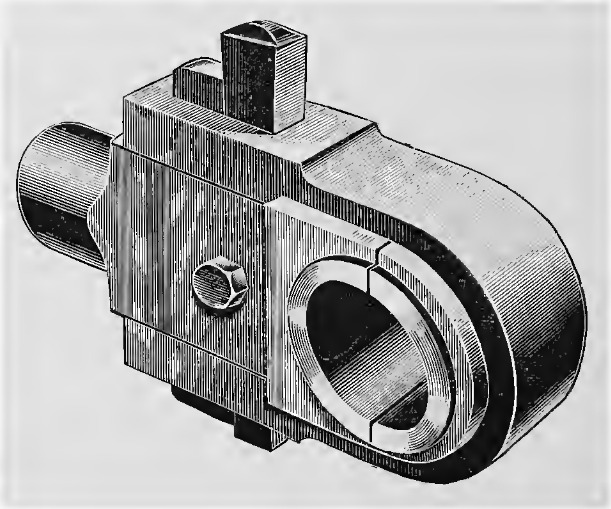


Fig. 1, and the perspective illustration, show one form of wrought iron or steel connecting rod end. This has been extensively used, but it is not adapted for quick running engines. The end of the rod E, which is rectangular in section, is slotted, to receive the gib B and the cotter A. The brasses D are in two parts, one having a flat end which butts against the end of the rod, and the other, a semicircular end fitting into the strap C.

The strap passes round the brasses, and fits upon the end of the rod. Slots are cut through the two sides of the strap corresponding with that in the rod end. The gib and cotter pass through these slots, and draw the brasses tightly together, clearance being left in the slots to admit of the *draw* of the cotter. The heads on the gib fit exactly on the outside of the strap, and so keep it in contact with the flat end of the rod. The wear, which is principally in the direction of the length of the rod, is taken up by the forward movement of the cotter. A set screw prevents the cotter from working back by the vibration of the rod.

Fig. 2 shows a solid connecting rod end. This form is stronger and more reliable than the previous one. The brasses C are of uniform thickness. One fits against the semicircular end of the hole, and the other against a movable block B. A steel wedge A, which is moved by a screw, acts on the back of B, keeps the brasses in contact, and adjusts them for wear.

The brasses are fixed sideways by flanges cast on their faces. The method of finding the curve of intersection of the round end with the flat sides is shown in the diagram.

Fig. 3 represents a short link used for connecting the air pump rod of a marine engine with the lever, which receives an oscillating motion from the crosshead.

The ends are made entirely of brass; the two parts D D being held together by steel rods which pass through them. The same rods, with increased diameter, serve to connect the two ends together.

EXERCISES.

1.—Draw the two views of the rod end as given in Fig. 1, adding an end elevation. *Scale 9″ = 1 foot.*

2.—Draw Fig. 2, showing also an end elevation. *Scale 6″ = 1 foot.*

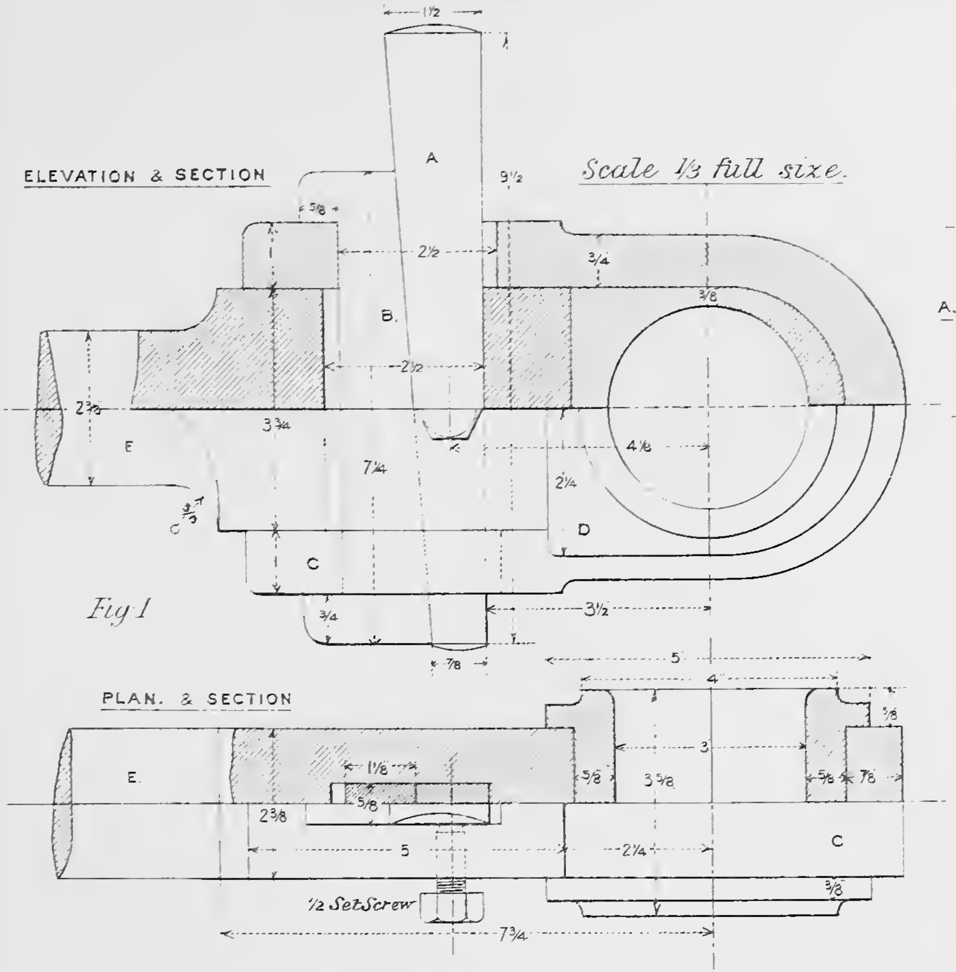
3.—Draw Fig. 3, adding an end elevation and plan. *Scale 6″ = 1 foot.*

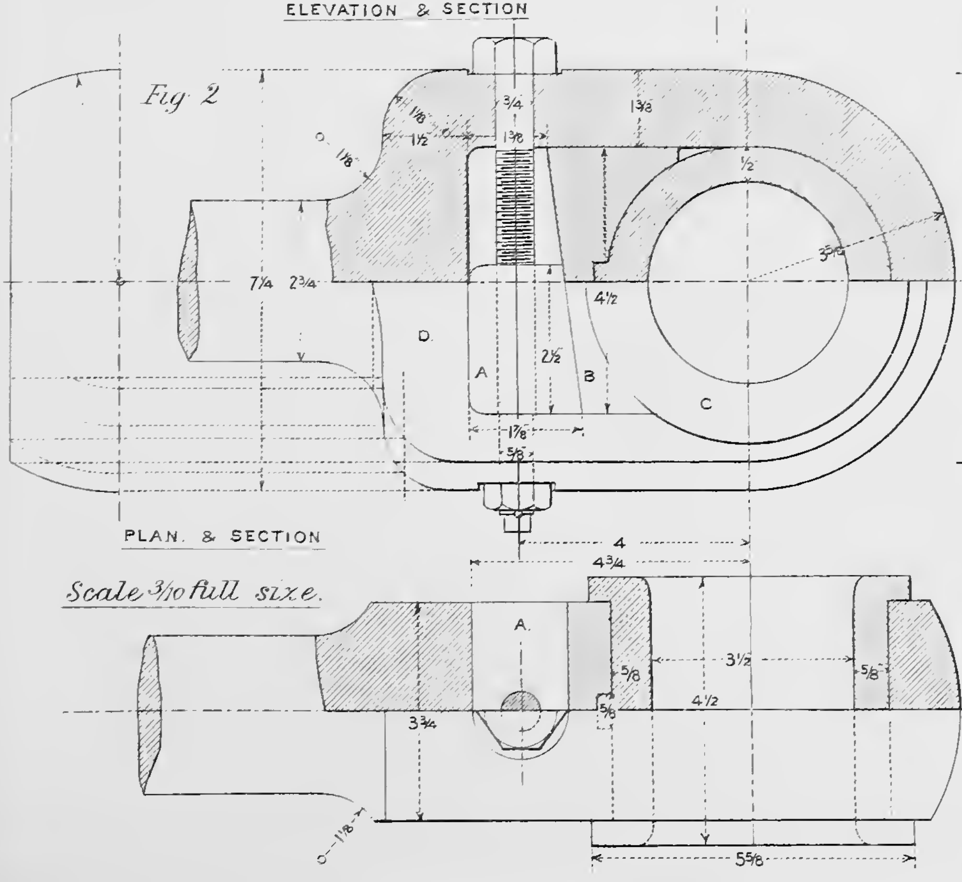
QUESTIONS.

1.—Give sketches of a connecting rod for a steam engine, and explain how the exact length of the rod may be maintained whilst adjustment is made for the wear of the brasses.

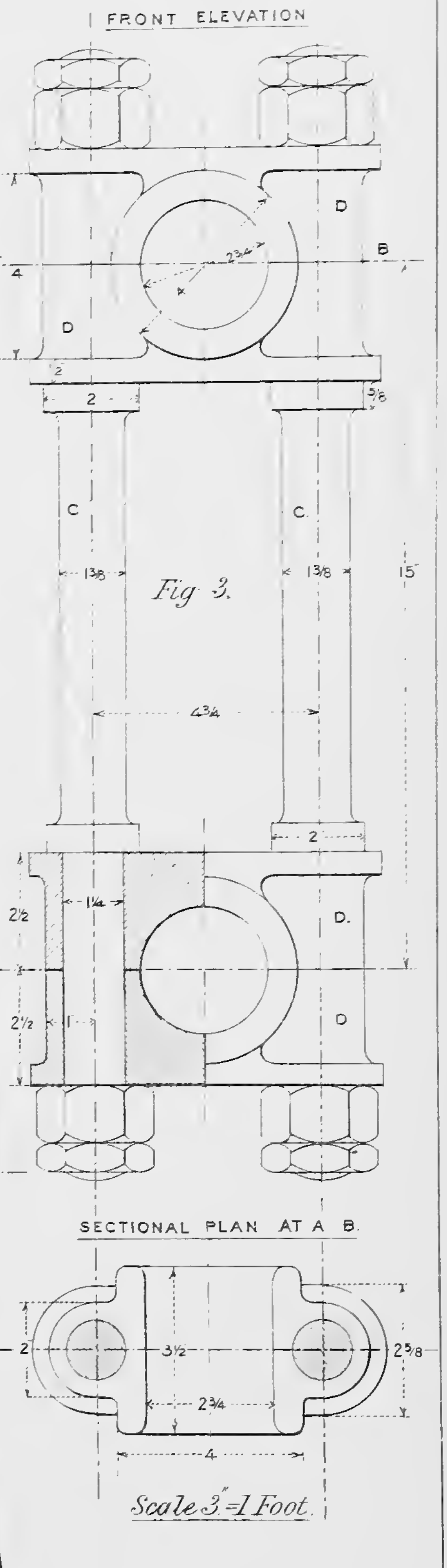
2.—Show, by sketches, two methods of preventing the cotter in a connecting rod end from *slackening back.*

CONNECTING ROD ENDS.





LINK FOR AIR PUMP.



T. JONES.
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Plate XXIII.—MARINE CONNECTING ROD ENDS.

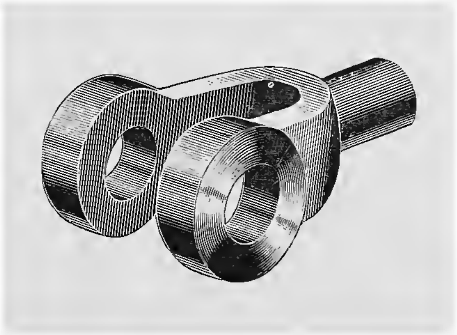
CONNECTING rod ends for marine engines are constructed as shown in this plate. This type is also very often used in stationary engines.

Fig. 1 shows the crank pin end of a steel connecting rod for a large engine. The end of the rod **P** is forged in one piece, a recess being planed across it to receive the brass **M**.

The top and bottom brasses **M M**, fit into this end and into the cap **L**, which is also made of steel and recessed. Packing pieces **N**, in the form of the letter **U**, are placed between the brasses. These can be removed and planed thinner, when the brasses require adjusting for wear, by simply slacking the bolts without taking them out of their places.

The two steel bolts hold all the parts together as shown, the grooved nuts being locked by set screws. The brasses and packing pieces are cored out to lighten them and also to reduce their cost.

Figs. 2 and 3 and the accompanying illustrations show the crank pin end and crosshead end of a steel connecting rod for a small launch engine.



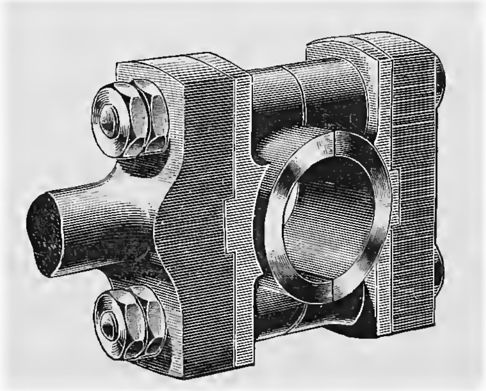


Fig. 2 is similar in constructon to Fig. 1, but no packing pieces are shown between the brasses, and the nuts are secured by lock nuts instead of set screws.

The packing pieces are often made of thin wrought iron plates $\frac{1}{8}''$ to $\frac{3}{16}''$ thick; when the brasses require adjusting for wear, one or more of these plates can be removed, and no planing of the packing is required.

The crosshead end is forked, as shown in Fig. 3. The holes are not brass bushed, so the crosshead pin must be made fast in the forked end of the rod. The crosshead will have to be provided with adjustable brasses similar to the one shown in Fig. 1, Plate XXV.

EXERCISES.

1.—Draw the three views partly in section as given in Fig. 1, and add a sectional side elevation by a plane passing through the centre of a bolt. *Scale 6″ = 1 foot.*

2.—Draw the views of Figs. 2 and 3, as given, and add a plan of each; show also a sectional side elevation of Fig. 2 by a plane passing through the axis of the crank pin. *Scale 6″ = 1 foot.*

CONNECTING ROD ENDS FOR MARINE ENGINES.

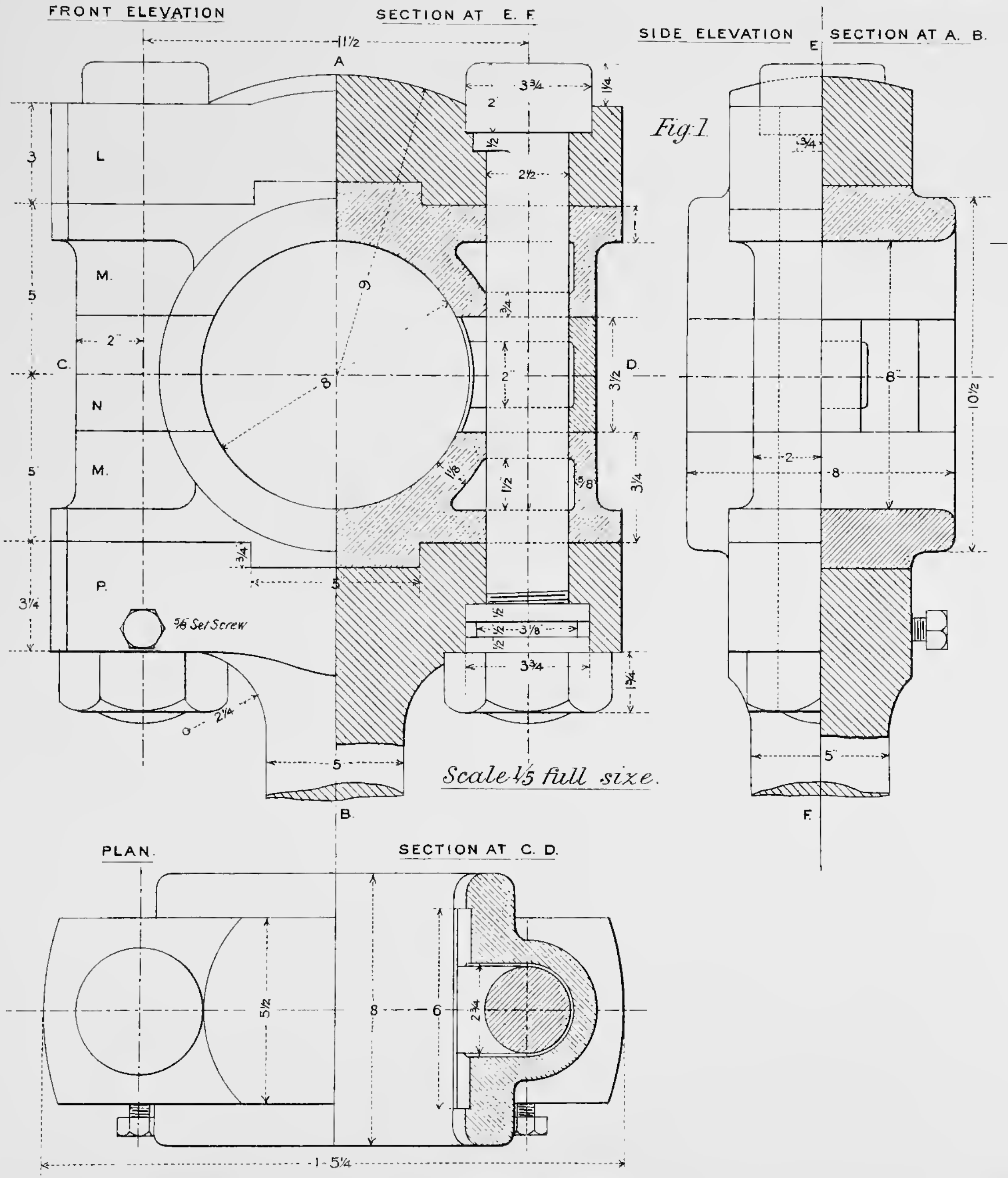


Fig. 1

Scale ⅕ full size.

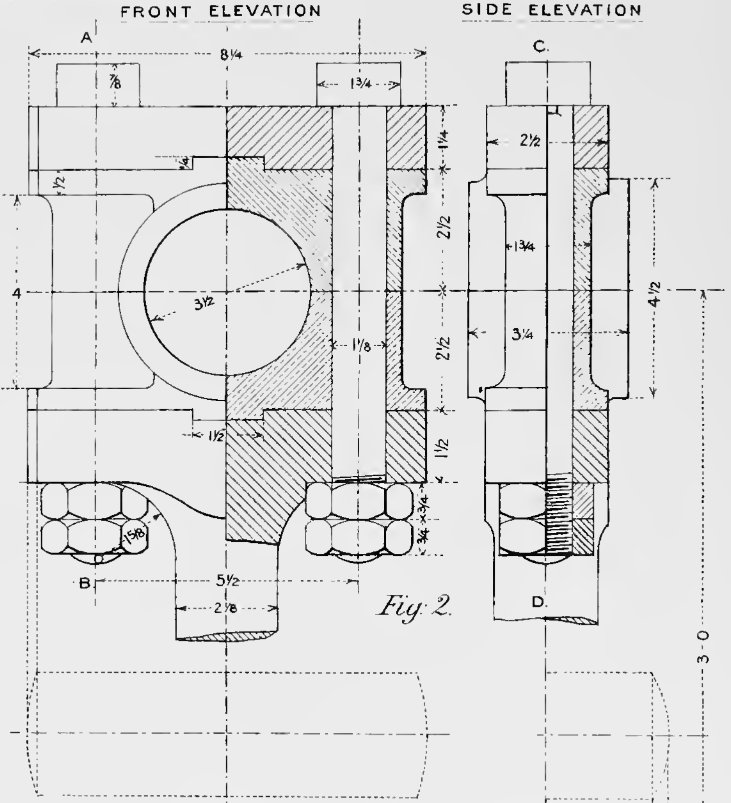


Fig. 2

Scale 3" = 1 Foot.

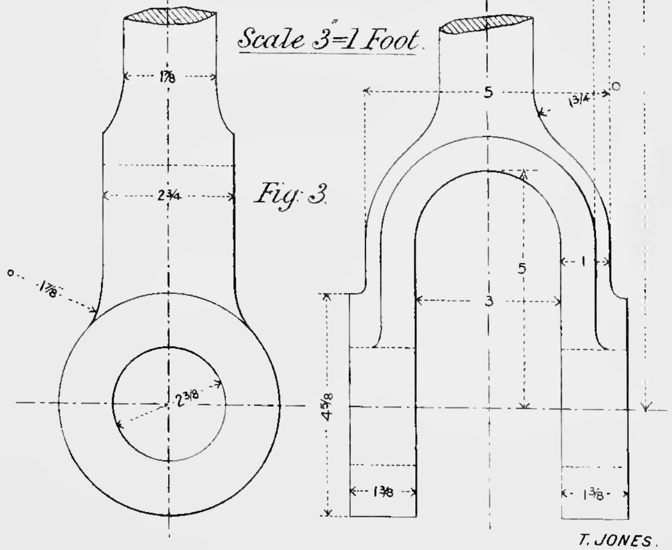


Fig. 3

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Plate XXIV.—LOCOMOTIVE COUPLING AND CONNECTING ROD ENDS.

COUPLING rods are used for transmitting motion from one crank to another in the same plane. They are used in locomotive engines for coupling one or more pairs of wheels to the driving wheels.

The rods are made of steel and have solid ends forged on them, which are lined with brass bushes, and no adjustment for wear is provided; the bushes are replaced when worn.

Fig. 1 shows four views of a steel coupling rod end. The brass bush has one flange and is keyed to the end of the rod. The crank pin is shouldered on one side and the end turned down and screwed for a nut. The nut is made with a washer forged to it, which forms a second shoulder for the crank pin. The rod end works between these shoulders, and so is kept in position on the crank pin. The nut should be secured by a round pin passing through it into the end of the pin. The method of lubrication is shown.

Fig. 2 shows the crank pin end of a locomotive connecting rod. The rod end **A** is forked, the open end of the fork being closed by a block **B** held in position by the bolt **E**, which is screwed at both ends for nuts and lock nuts.

The brasses **C** have flanges on each side. They are tightened up by a wedge-shaped block **D**, which is adjusted by means of a double ended bolt screwed at both ends and fastened to the block by two pins.

The rod is made of steel and is rectangular in section. It has the greatest section at the crank pin end and tapers uniformly to the crosshead end.

EXERCISES.

1. Draw the views of Fig. 1 as given, and add an end elevation. *Scale 6″ = 1 foot.*

2. Draw the views of Fig. 2 as given, and add a plan and two end elevations, looking in opposite directions. *Scale 6″ = 1 foot.*

LOCOMOTIVE COUPLING AND CONNECTING ROD ENDS.

COUPLING ROD.

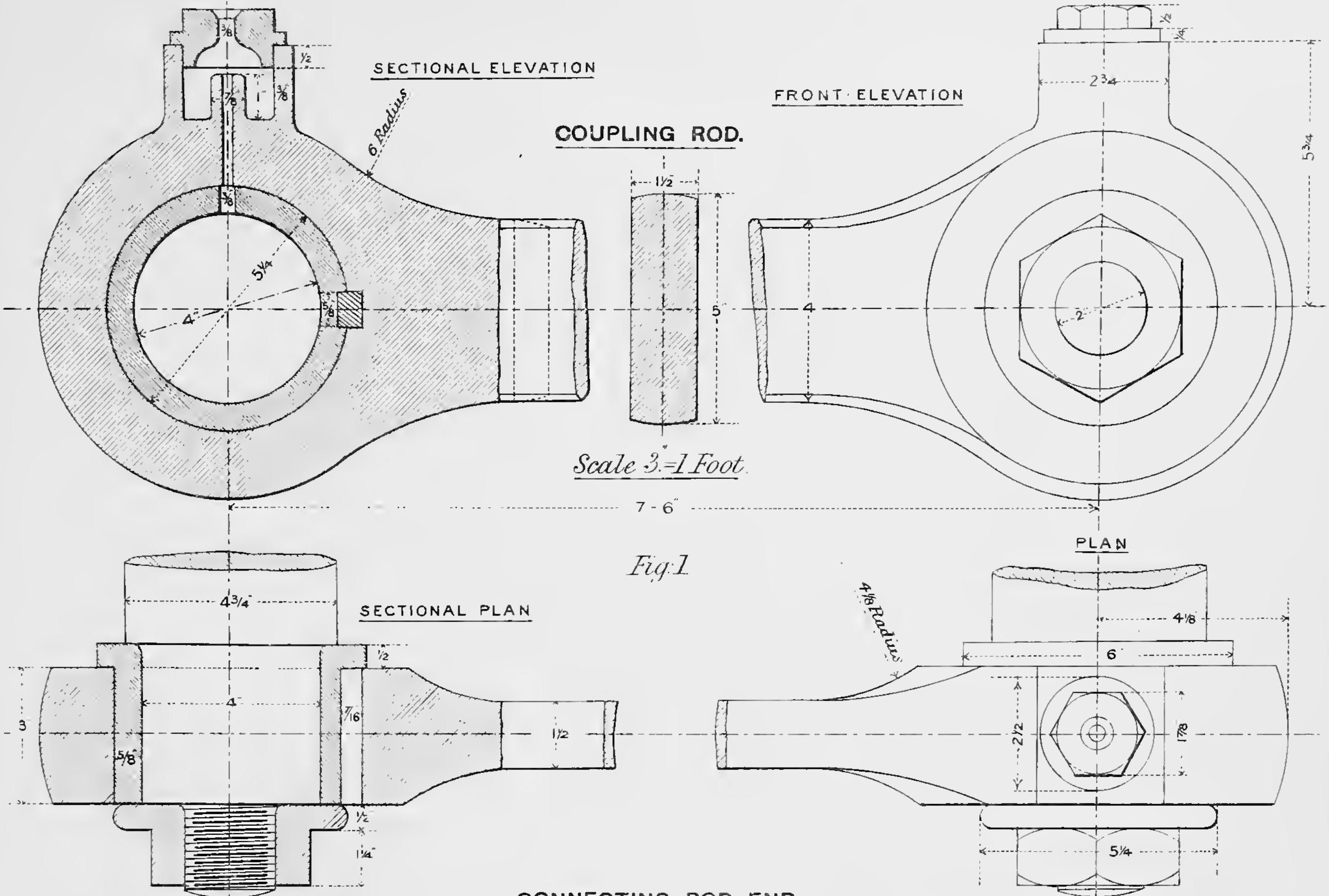

Fig. 1

CONNECTING ROD END.

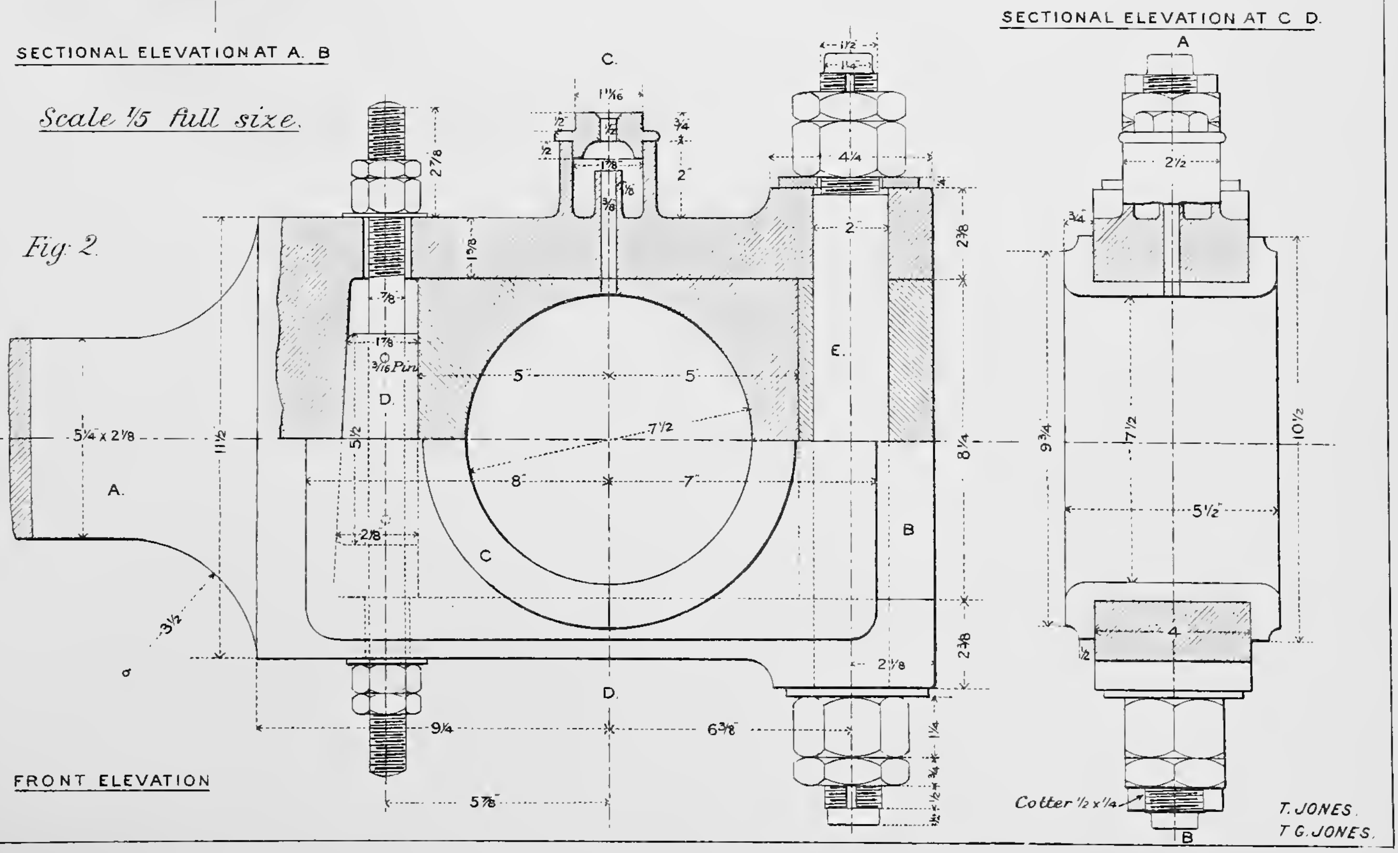

Fig. 2

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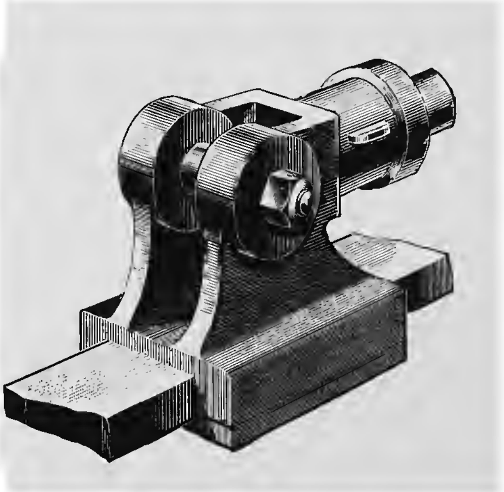
Plate XXV.—ENGINE CROSSHEADS.

ENGINE Crossheads, in conjunction with slide bars, are used for guiding the piston rod in a straight line; and for resisting the thrust or pull of the connecting rod, when it is inclined to the line of direction of the piston rod. (See line diagram of engine shown in notes to Plate XIX.) The end of the piston rod is usually turned to fit a hole bored in the crosshead, to which it is secured by a cotter.

The end of the connecting rod is also fitted to the crosshead. A round pin passing through both, connects them together and also allows for the oscillating motion of the connecting rod. The slide bars are either cast as part of the engine bed or are bolted firmly to it.

Fig 1 shows a steel crosshead for a vertical engine. The piston rod **A** has an end forged to it, which carries the slide block **B** and the brasses **C**. The parts are held together by the cap **D** and the two bolts. This form of crosshead admits of adjustment for wear. The base of the block **B** moves in slides, bolted fast to the engine bed.

Fig. 2 and the accompanying illustration, shows a form of cast iron crosshead used for small horizontal engines.



The end of the piston rod **C** is turned slightly conical, the hole in the crosshead being bored to fit. They are then fastened together by the cotter.

The body of the crosshead **A** is made of box section. The end of the connecting rod fits in the recess in the crosshead, and the pin **D** connects them together.

The base of the crosshead is fitted to the slide bar **B**, upon which it can move freely. The drawing shows the crosshead placed in position on the slide bar. The bottom cast iron plate secured by six small set screws, keeps the crosshead down on the bar. There is no stress on this plate when the engine is working, since the pressure, due to the obliquity of the connecting rod, is on the top side of the bar.

The pin **D** is made conical where it fits into the sides of the crosshead; but the part to which the connecting rod end is attached is cylindrical.

EXERCISES.

1.—Draw the three views of Fig. 1, completing the plan. *Scale 9″ = 1 foot.*

2.—Draw the three views of Fig. 2, as given, and add an end elevation looking on the end of the piston rod. *Scale 6″ = 1 foot.*

ENGINE CROSSHEADS.

CROSSHEAD FOR VERTICAL ENGINE.

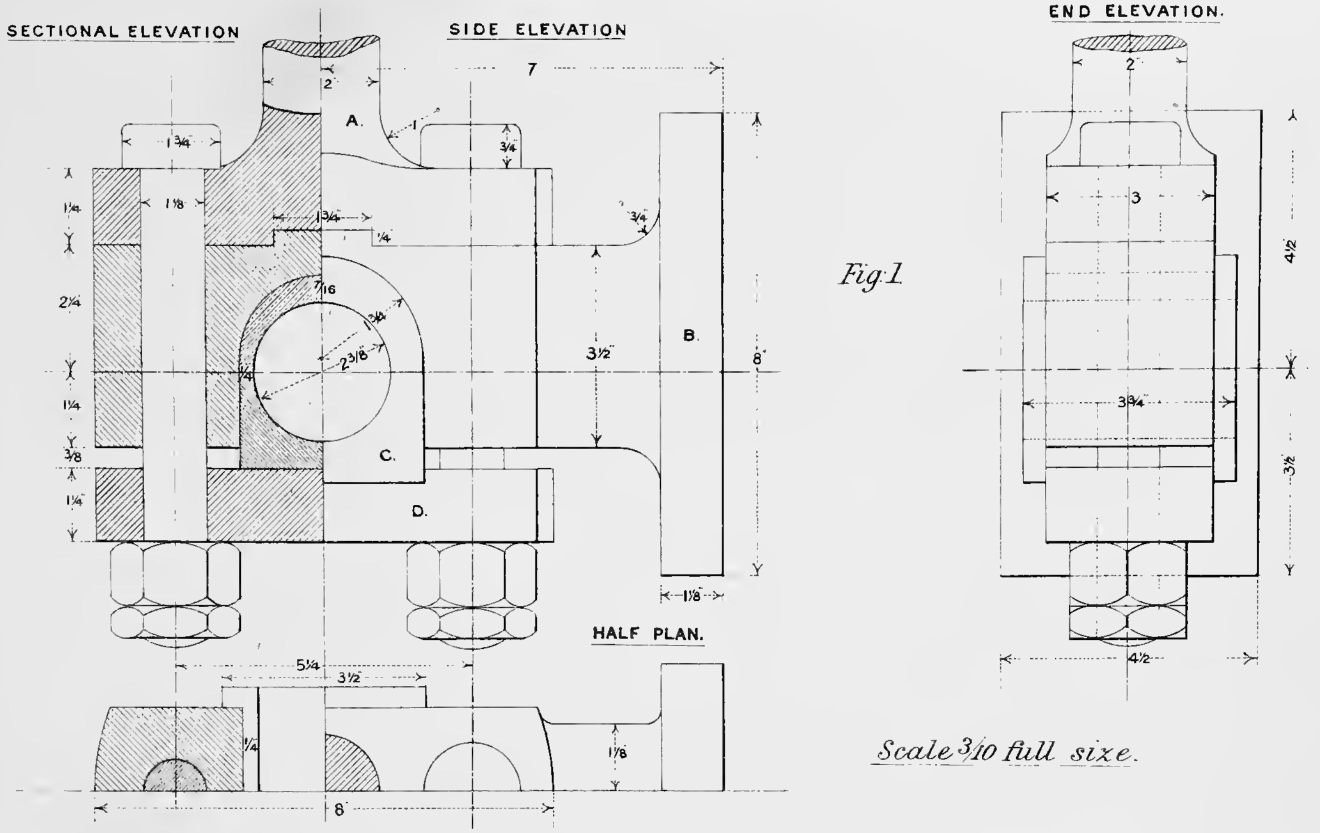


Fig. 1.

Scale 3/10 full size.

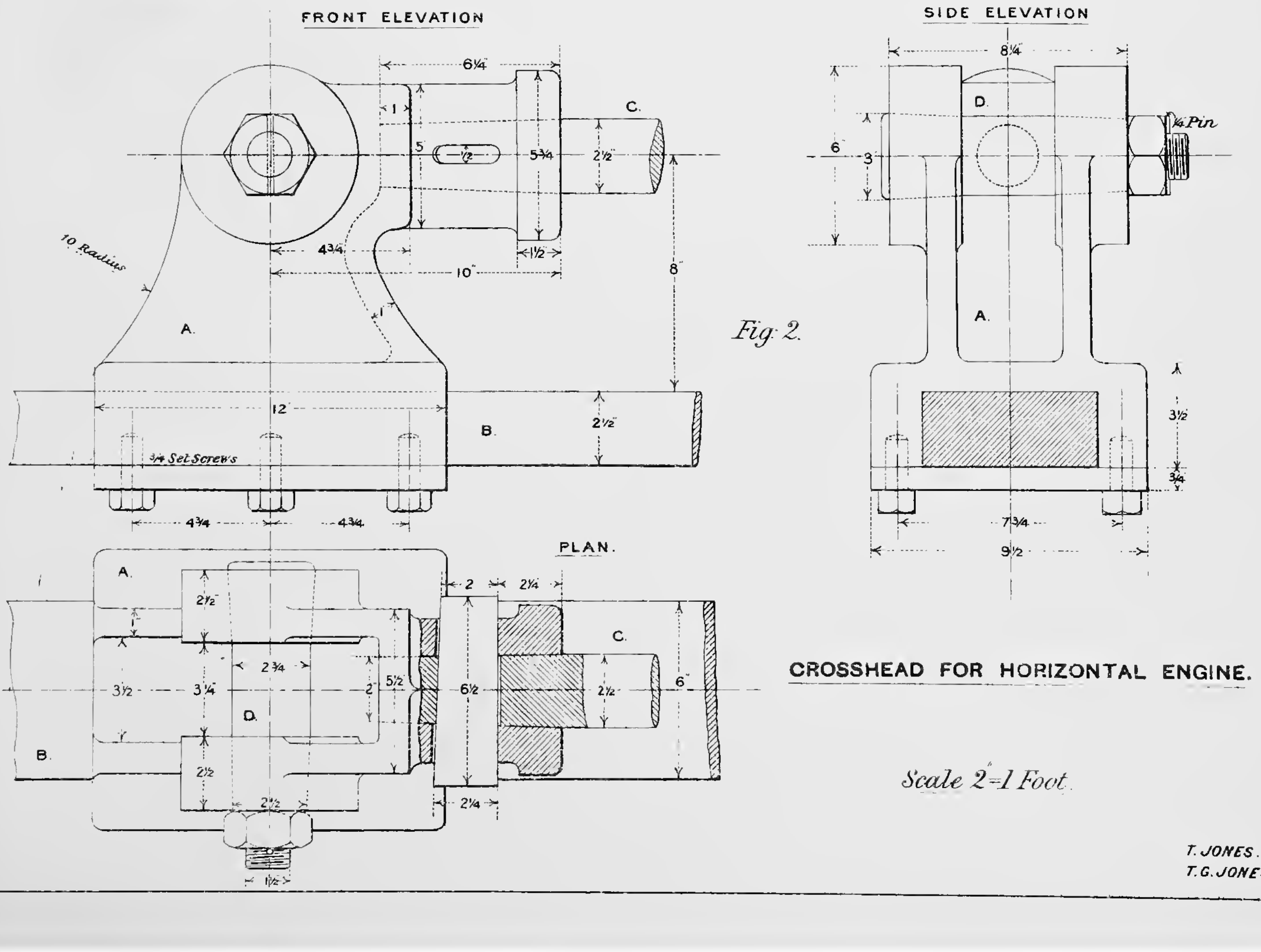


Fig. 2.

CROSSHEAD FOR HORIZONTAL ENGINE.

Scale 2" = 1 Foot.

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Plate XXVI.—ENGINE CROSSHEADS.

FIG. 1 shows a form of crosshead, with adjustable guide blocks or slippers, as used for large horizontal condensing engines. The central piece is a cubical block of steel **B**, with pins forged on each side to attach to the connecting rod. On the ends of these pins small bearings are turned, to connect to the levers working the air pumps.

The block **B** is bored to fit the end of the piston rod **A**, which is fastened to it by means of a nut screwed to the end of the piston rod.

The slippers **E E** are carried by two steel pins **C C**, screwed to receive lock nuts for adjustment. Each carrier is attached to the central block, by four steel set screws.

The slippers are made of cast-iron, and they run in cast-iron guides of ⊔ section, which are bolted to the engine frame. The lock nuts **D** are cylindrical in form, each having four grooves or notches cut into them, to receive the key for turning.

Fig. 2 shows a form of wrought-iron crosshead used for horizontal engines, and also for single acting vertical air pumps.

The steel piston rod **A** is attached to the crosshead **B**, as before described. The steel pin **C**, which is keyed fast to the crosshead, is provided with long ends for carrying the cast-iron slippers **D D**. The slippers run in cast-iron slide bars of ⊔ section.

EXERCISES.

1.—Draw the two given views of **A** and **B**, Fig. 1, and add a plan and section, by a vertical plane passing through the axis of the piston rod. *Scale* $\frac{3}{8}$ *full size.*

2.—Draw elevation, plan, and sectional elevation of the carrier **C**, shown in Fig. 1. *Scale* 9″ = 1 *foot.*

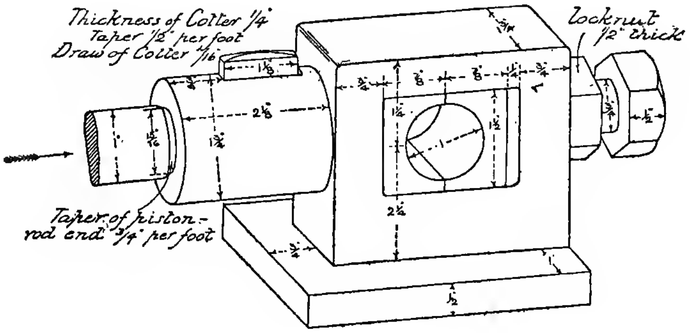
3.—Draw plan, elevation, and sectional elevation of the slipper **E**, shown in Fig. 1. *Scale* 6″ = 1 *foot.*

4.—Draw the complete crosshead, as shown in Fig. 1. *Scale* 3″ = 1 *foot.*

5.—Draw plan, elevation, and section of the slipper **D**, shown in Fig. 2. *Scale* 9″ = 1 *foot.*

6.—Draw the crosshead and pin, as shown in Fig. 2, and add a section, by a plane passing through the axis of the pin. *Scale* 6″ = 1 *foot.*

7.—Draw the complete crosshead, as shown in Fig. 2, and add a view, looking towards the forked end. *Scale* 4″ = 1 *foot.*



8.—Draw the crosshead, as shown in the above sketch, to the dimensions given. Show plan, side and end elevations, and a sectional elevation, by a vertical plane passing through the axis of the piston. *Scale* 9″ = 1 *foot.*

CROSSHEAD WITH ADJUSTABLE SLIDES.

FRONT ELEVATION

SIDE ELEVATION

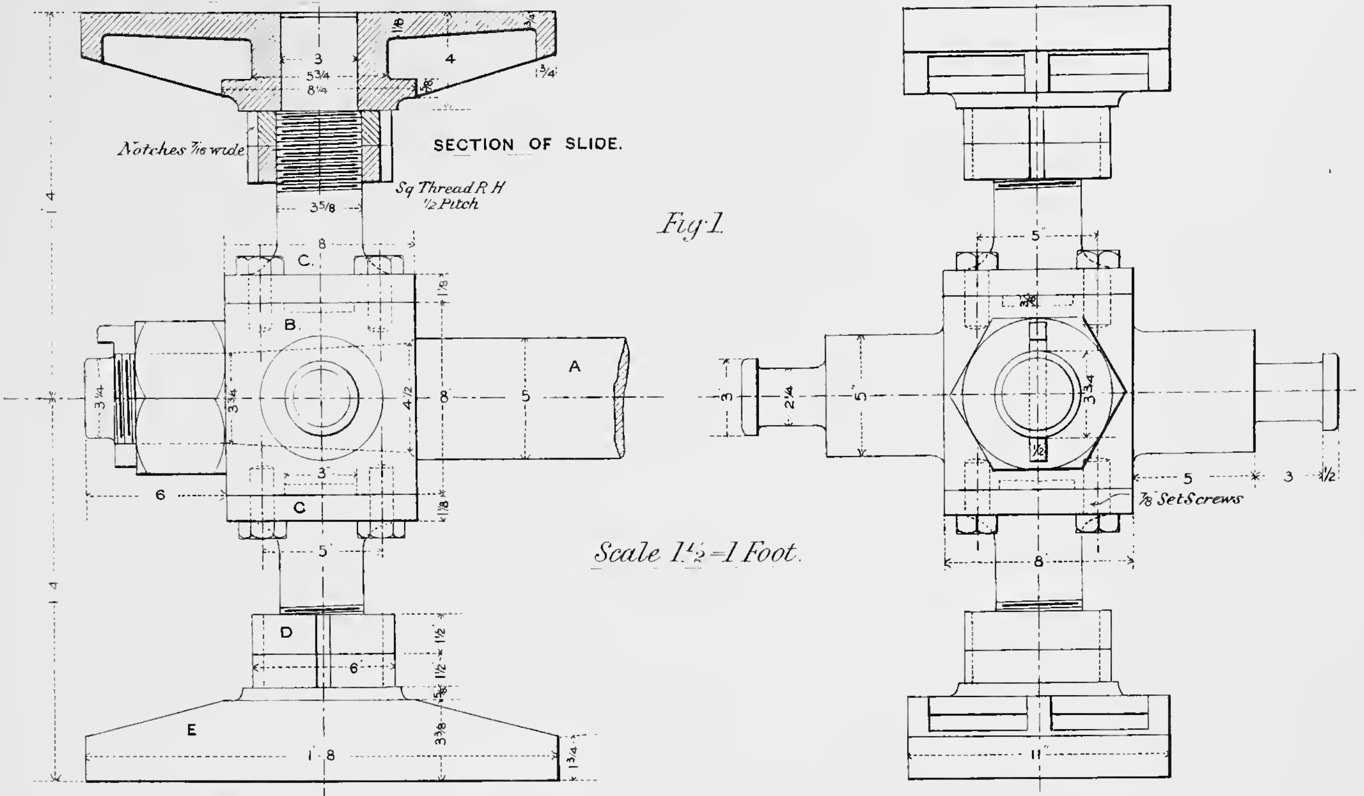
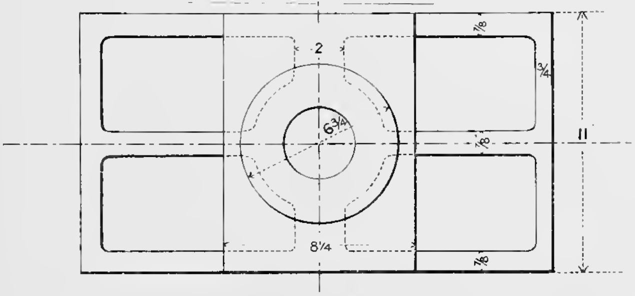


Fig 1.

Scale 1½ = 1 Foot.

PLAN OF BOTTOM SLIDE.



CROSSHEAD AND SLIDE BLOCKS

FOR HORIZONTAL ENGINE.

ELEVATION OF CROSSHEAD.

ELEVATION OF SLIDE.

PLAN.

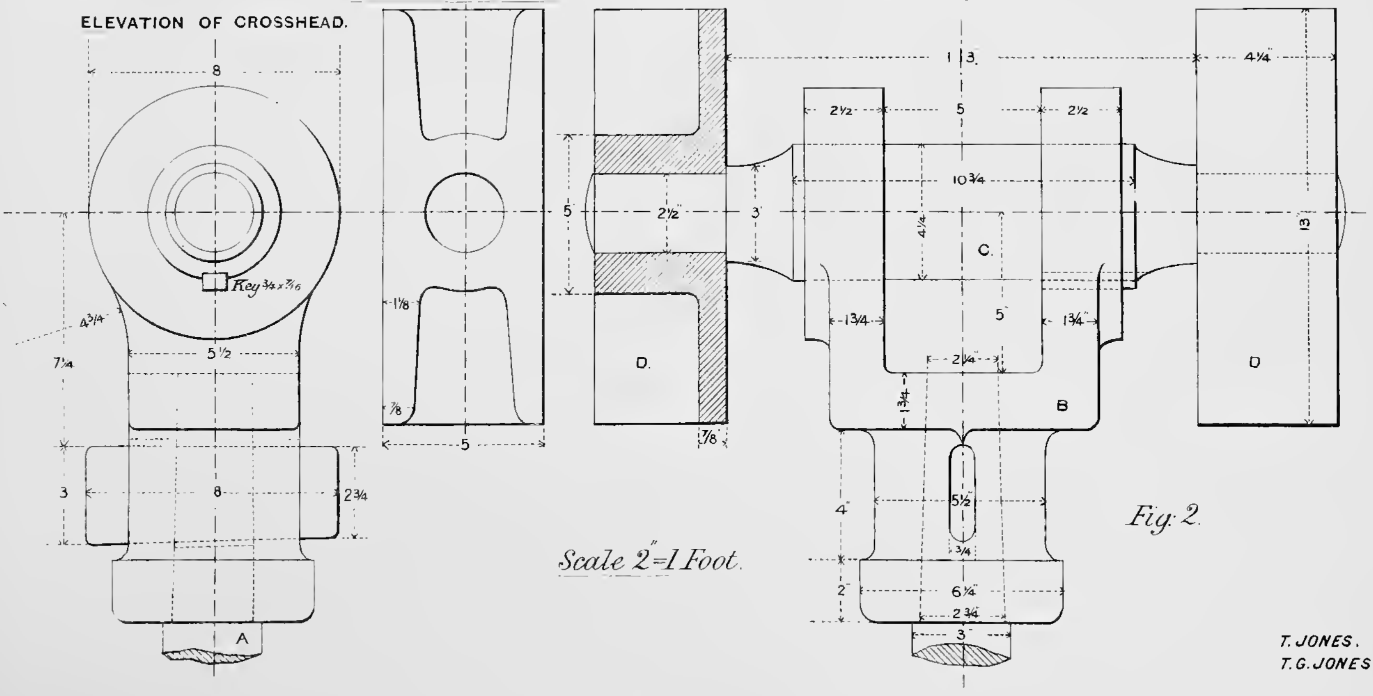


Fig: 2.

Scale 2" = 1 Foot.

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Plate XXVII.—ENGINE PISTONS.

THE piston of a steam engine is made in the form of a short cylinder. It fits inside the engine cylinder as shown in Fig. 1 below. The pressure of the steam causes it to move backwards and forwards in a straight line. In order to render the piston steam tight, and at the same time allow it to move freely in the cylinder, elastic packings are used. Various methods of packing are adopted by engineers, those shown in the drawings being the most common. The piston rod is fastened to the piston, either by a nut screwed on the end, or by a cotter passing through it. The steam pressure on the piston is transmitted through the rod to the crosshead, and thence through the connecting rod to the crank pin.

Fig. 1 shows the usual form of piston for a locomotive engine. The body **B** is made of cast iron, the piston rod **A** of steel, and the springs **C** of cast iron. The piston rod, the end of which is turned conical, is secured to the piston by a nut and small cotter. The Ramsbottom rings **C C** are made of cylinder cast iron. They are turned to $18\frac{3}{8}''$ diameter, a piece is cut out of them and they are sprung into their places.

Fig. 2 and the illustrations given below show the construction of a piston with the "Mather and Platt" patent packing. The body **B** is made of cast iron, the piston rod **A** of steel, the casing **D D** of cast iron, and the helical coil or spring **C** of tempered steel. The piston rod end is turned conical and secured to the piston by the steel cotter. The casings which are turned to a larger diameter than that of the cylinder are cut across at an angle. The helical spring is also made of larger diameter than the inside of the casing when in its place in the cylinder. The spring is placed inside the casing, and the whole fixed in position on the piston by removing the cast iron junk ring **J**. The junk ring is then replaced and held securely by the set screws. The gap in the casing is covered by the brass making-up piece shown in Fig. 3.

Fig 1.

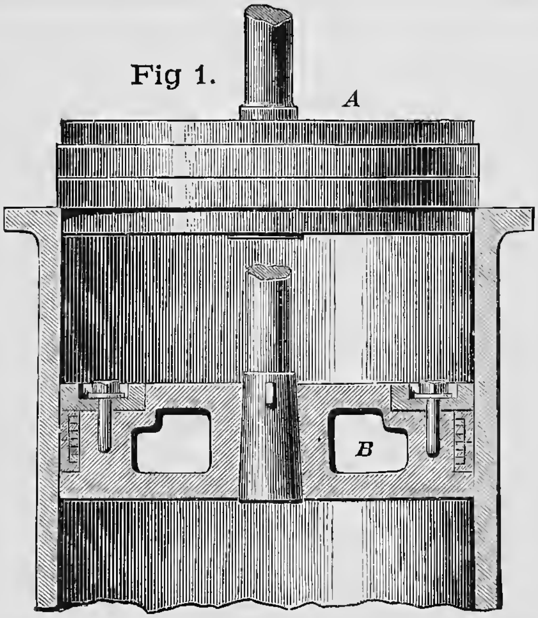
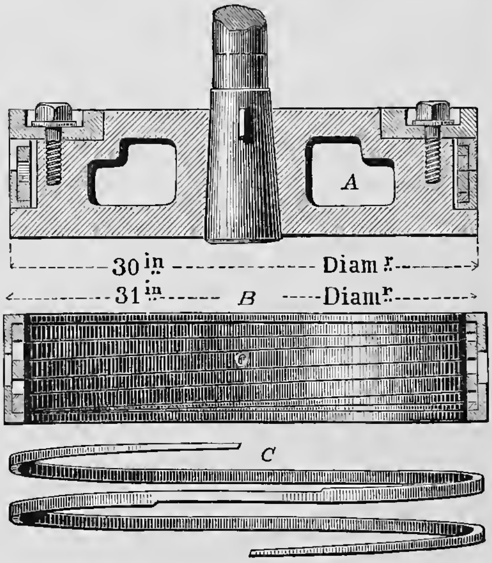


Fig 2.



The above illustrations, which have been supplied by the makers, show the advantages of this form of packing.

Fig. 1 A gives an elevation of the piston with the packing expanded. Fig. 1 B shows a sectional elevation of the piston when in position in the cylinder.

Fig. 2 A. Vertical section of the piston for a cylinder 30″ diameter. Fig. 2 B. Vertical section of the packing when out of the cylinder, expanded to 31″ diameter. Note that the packing has a *vertical* spring as well as a circumferential one. Fig. 2 C shows an elevation of the helical spring.

EXERCISES.

1.—Draw the two views of the locomotive piston, Fig. 1, and add a plan. *Scale* $\frac{3}{8}$ *full size.*

2.—Draw the 12″ piston as given in Fig. 2. *Scale 9″ = 1 foot.* And show the making-up piece, Fig. 3. *Full size.*

PLATE XXVII

LOCOMOTIVE PISTON.

Scale 2"=1 Foot.

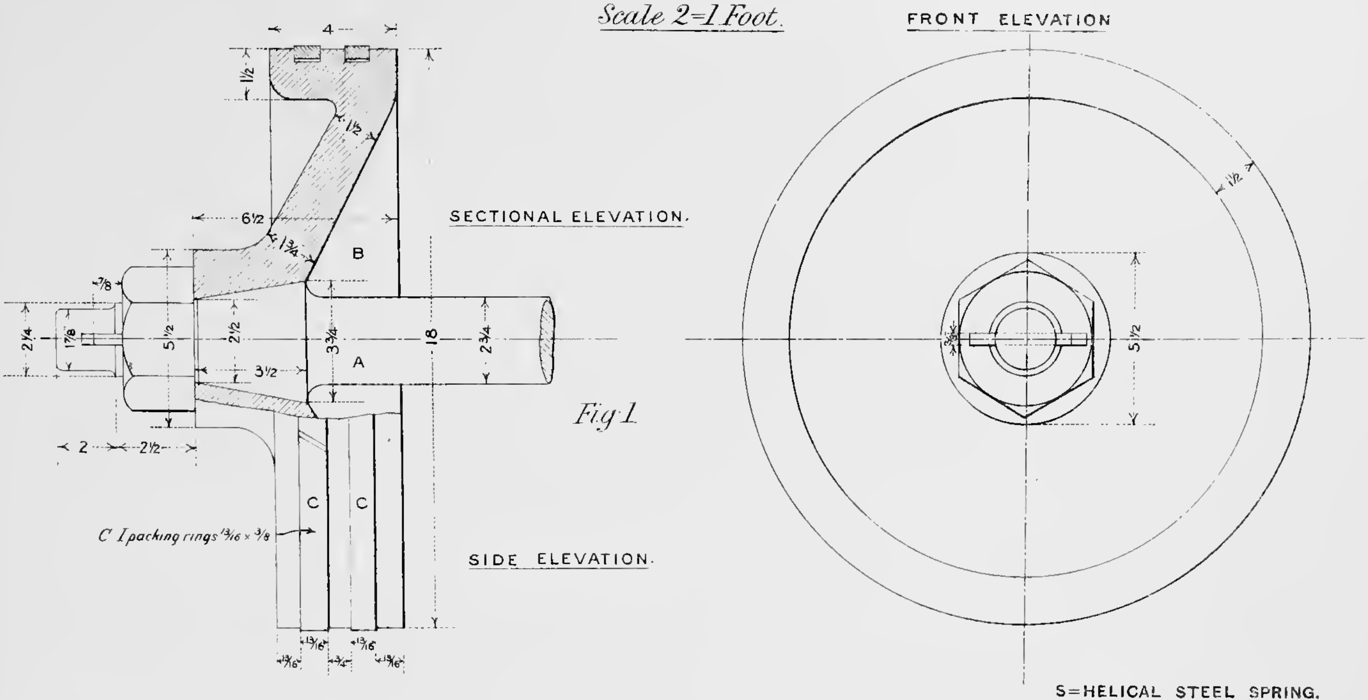


Fig 1.

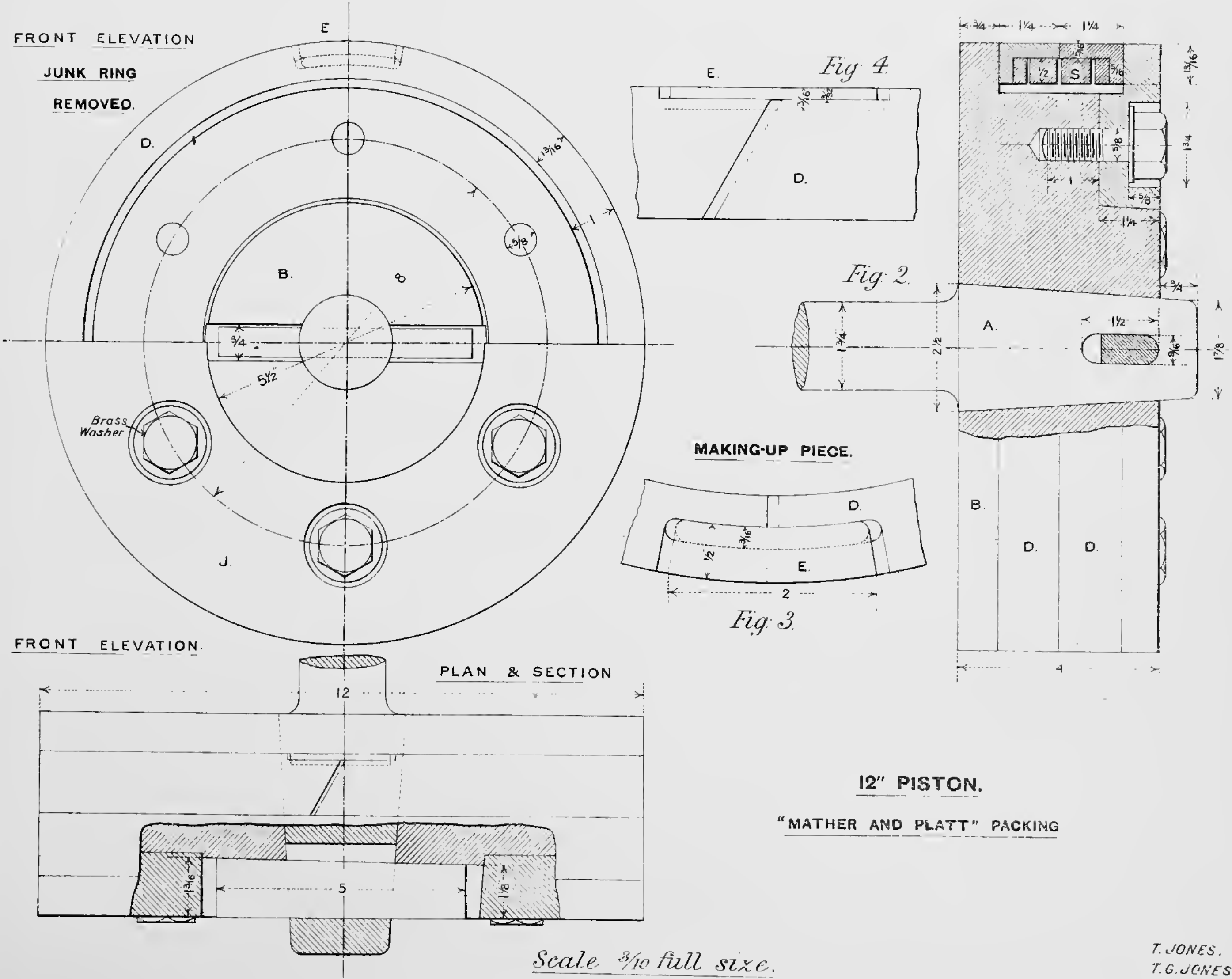


Fig 4

Fig 2.

Fig 3.

12" PISTON.

"MATHER AND PLATT" PACKING

Scale 3/10 full size.

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Plate XXVIII.—36″ PISTON.

THE packing for this piston consists of a straight spiral steel spring, of oval form, which is placed inside the cast-iron packing rings or casings **D D.** These casings are turned a little larger in diameter than the bore of the cylinder. Short lengths are cut out of them, so that they may be compressed into a diameter equal to that of the cylinder. The steam is prevented from passing the piston by small making up pieces, which close the slits in the casings. The Junk ring **C** is secured to the body **B** by screws, which have brass nuts **K** fitting in recesses cast in the body of the piston.

The internal wedge shape of the casings, tends to change the oval form of the coil into a circular one. This gives a vertical pressure to the casings, as well as an outward or circumferential one.

The body **B** of the piston is cast hollow and stiffened inside by ten thin webs. The piston rod **A** is turned conical to fit the hole bored in the piston, to which it is secured by a nut and small cotter.

The piston rod, which is carried through the piston and turned to a smaller diameter, passes through a stuffing box and gland at the back of the cylinder. This helps to carry the piston and so prevent undue wear on the lower side of the cylinder.

EXERCISE.

Draw the several views of the 36″ piston to dimensions given. *Scale 3″ = 1 foot.*

QUESTIONS.

1.—If the casings of a 36″ piston are turned $36\frac{1}{2}$″ diam., find the amount to be cut out so that it may fit the cylinder.

2.—Explain the advantage of the Junk ring screws, fitting into brass nuts instead of into the body of the piston.

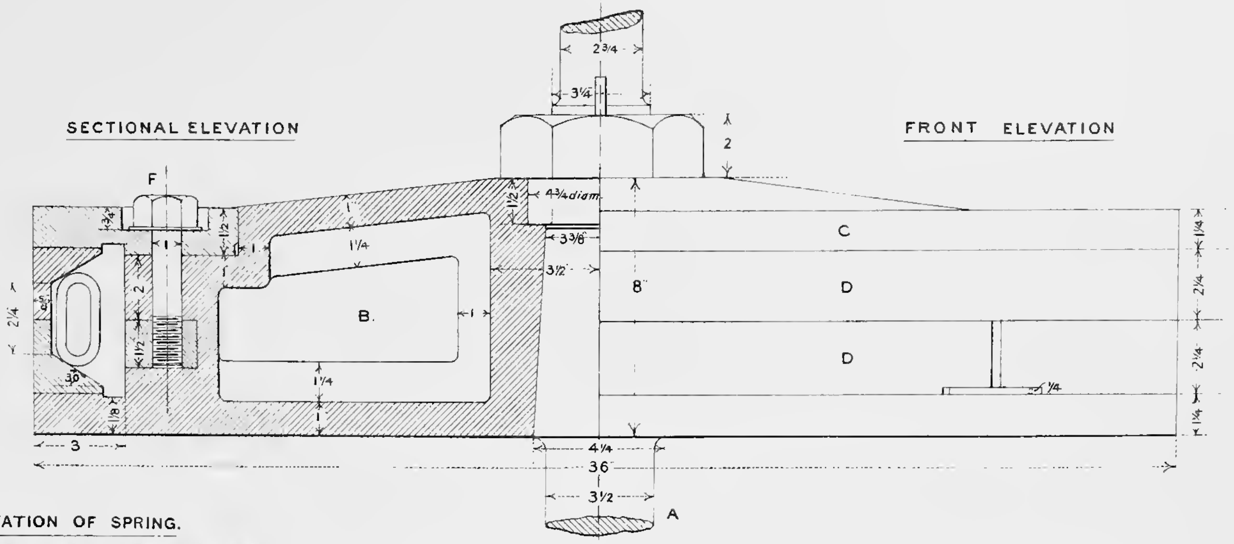
3.—Distinguish between a piston, a plunger, and a pump bucket. Give a sketch of each.

36" PISTON.

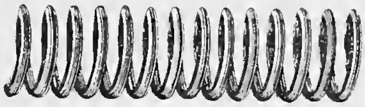
Scale 2"=1 Foot.

SECTIONAL ELEVATION

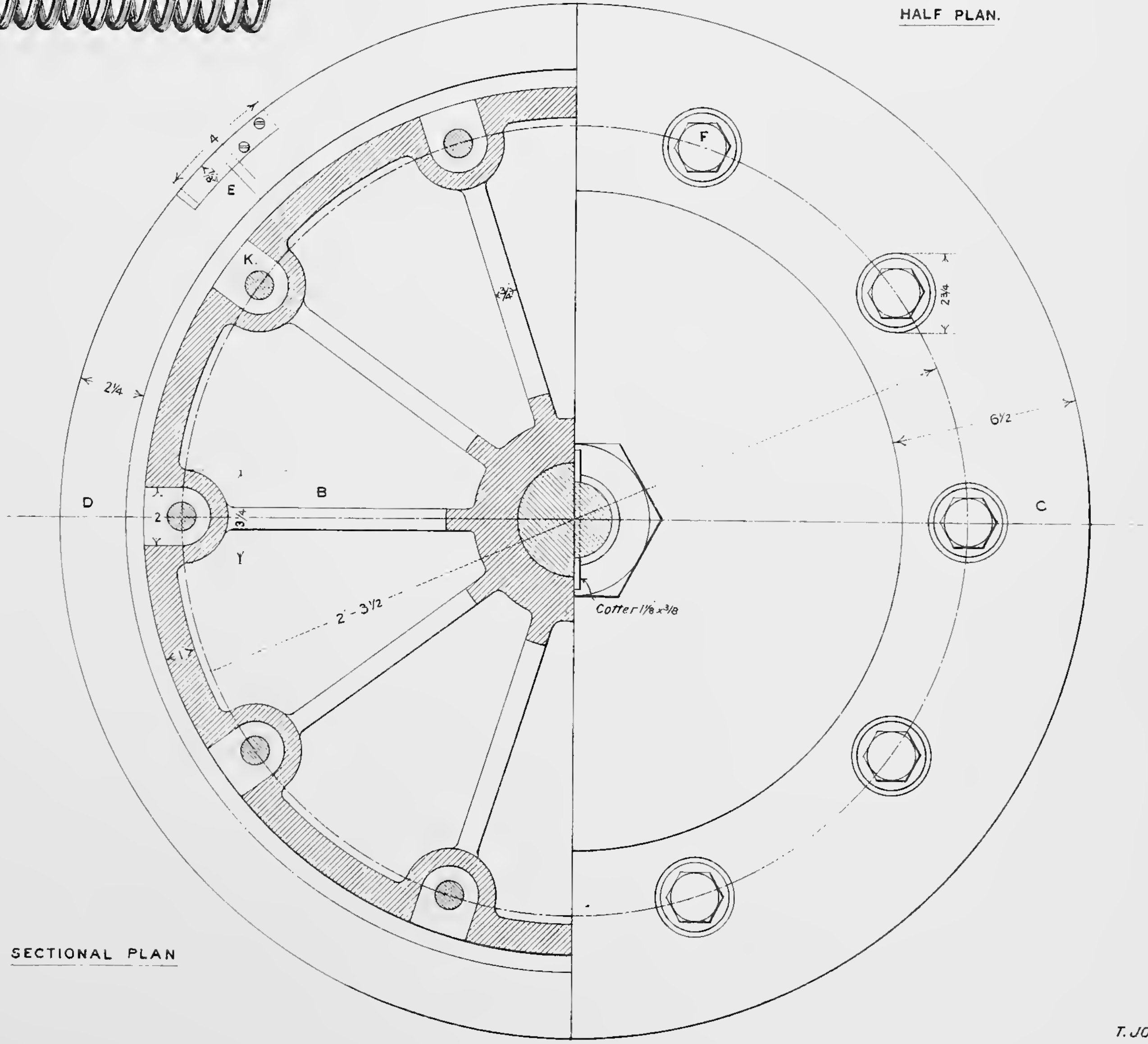
FRONT ELEVATION



ELEVATION OF SPRING.



HALF PLAN.



SECTIONAL PLAN

T. JONES.
T G. JONES.

Plate XXIX.—DETAILS OF ENGINE CYLINDER.

When the motion of a sliding or rotating piece inside a vessel, is transmitted to parts external to it or *vice versa*, the cylindrical rod, to which the moving piece is attached, must pass through the vessel without the leakage of any of the working fluid, and also with very little friction.

Stuffing boxes and glands are used for this purpose, as in the steam engine, where the piston rod passes through the cylinder cover; also, where the valve spindle passes through the end of the steam chest.

An annular space is formed round the rod, which is filled with soft packing, either of hemp saturated with tallow, or asbestos. The packing is pressed into the cavity or stuffing box, by means of a gland, which is held in position by stud bolts, attached to the flange of the stuffing box. Metallic packings of various kinds are also used.

Fig. 1 shows the cast-iron front cover C of a cylinder for a horizontal engine. It is secured to the flange of the cylinder by eight bolts and two stud bolts.

The end of the stuffing box B, and the whole of the gland A, are lined with brass. The gland is forced against the packing in the stuffing box, by the nuts screwed on the three stud bolts.

Fig. 2 shows the form of stuffing box B, and gland A, as used for a valve spindle. In this example only two stud bolts are necessary for the gland, and the flange is shaped to suit these. The parts through which the spindle passes are brass bushed, as in Fig. 1.

Fig. 3 represents a brass stuffing box and gland, as used for the spindle of a steam or water valve, or for the plunger of a small pump. The gland A is pressed into the stuffing box B, by the brass nut C, which screws on the outside of B. The nut is made hexagonal, so that it can be turned round with a screw key.

Fig 4 gives four views of a **short D slide valve,** as used for distributing the steam to the cylinder of a horizontal engine of 12″ diameter. It consists of a cast-iron box, with projecting edges or flanges. the face and edges of the valve are accurately planed; the face is made smooth and true, to slide upon the trued surface in the steam chest, which is called the cylinder face. See Plate XXX.

The pressure of the steam on the back of the valve keeps the valve face and cylinder face in contact, and so prevents leakage. In a horizontal engine the cylinder face is vertical. The valve is provided with a suitable bearing surface on its lower side.

In the cylinder face are three openings or ports—two for live steam, and one for exhaust steam. The steam ports communicate with the ends of the cylinder. The exhaust port communicates with the atmosphere, or the engine condenser. The exhaust steam leaves the cylinder by the steam passages, then passes through the cavity in the slide valve, and out through the exhaust port. The valve, in order to distribute the steam, travels backwards and forwards on the cylinder face. It receives its motion from an eccentric on the engine shaft. The valve rod passes through an elongated hole in the valve, to which it is secured by lock nuts. This arrangement admits of exact adjustment of the valve to the ports on the cylinder face.

EXERCISES.

1.—Draw the two views of the cylinder cover as given in Fig. 1, and add a plan. *Scale* $\frac{3}{8}$ *full size.*

2.—Draw the stuffing box and gland as shown in Fig. 2, and add a sectional plan. *Scale* 9″ = 1 *foot.*

3.—Draw the brass stuffing box, &c., as given in Fig. 3, and add an elevation. *Scale full size.*

4.—Draw and complete the four views of the slide valve. *Scale* 6″ = 1 *foot.*

QUESTIONS.

1.—Give sketches, showing one method of attaching the valve rod to an ordinary slide valve.

2.—With the aid of sketches, explain how a piston rod is made to work steam-tight through the end of a cylinder.

3.—Why are stuffing boxes and glands brass bushed?

PLATE XXIX

DETAILS OF ENGINE CYLINDER.

CYLINDER COVER WITH STUFFING BOX.

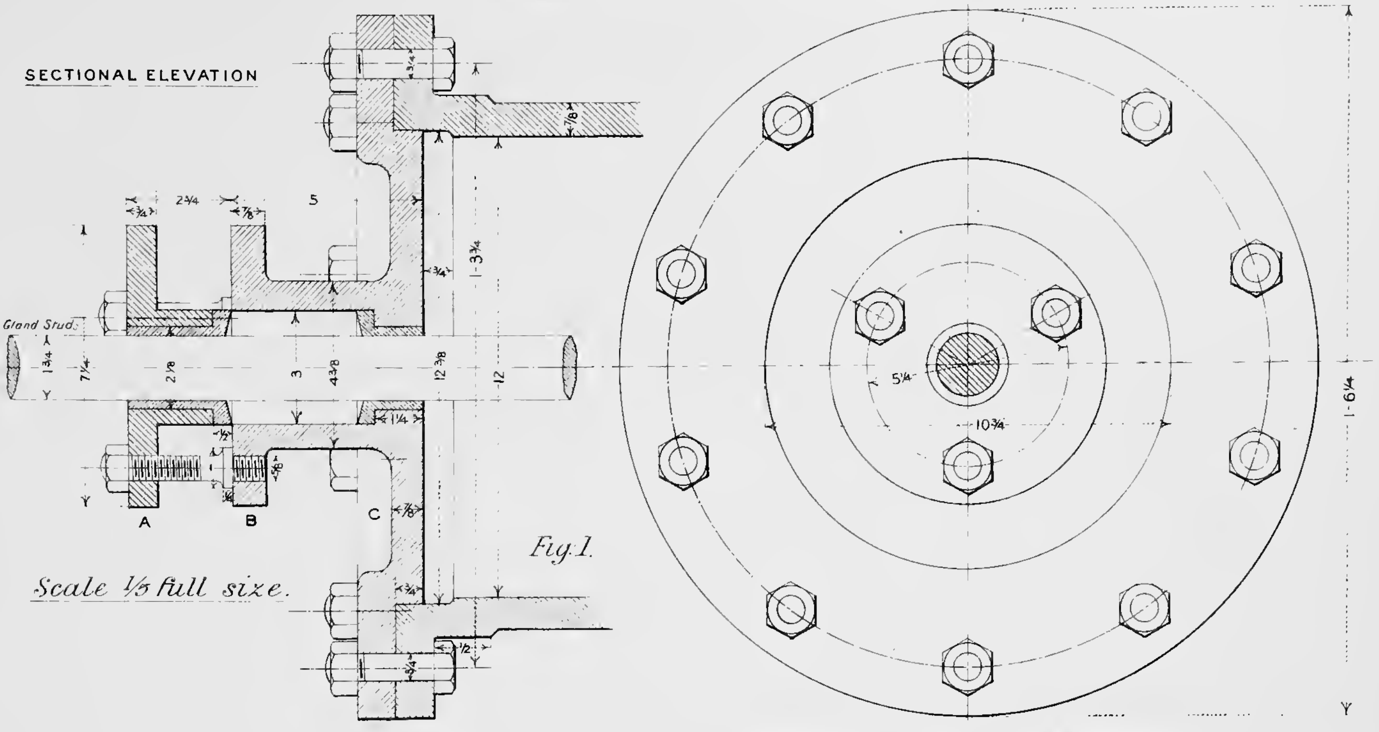


Fig. 1.

Scale ⅕ full size.

STUFFING BOX FOR VALVE SPINDLE.

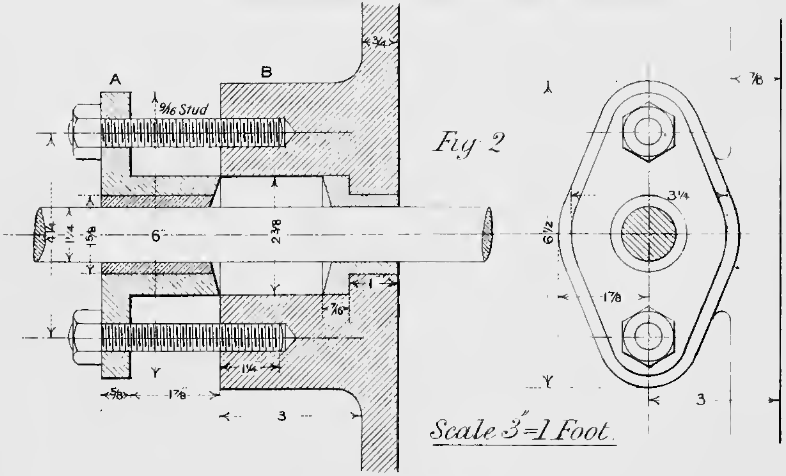
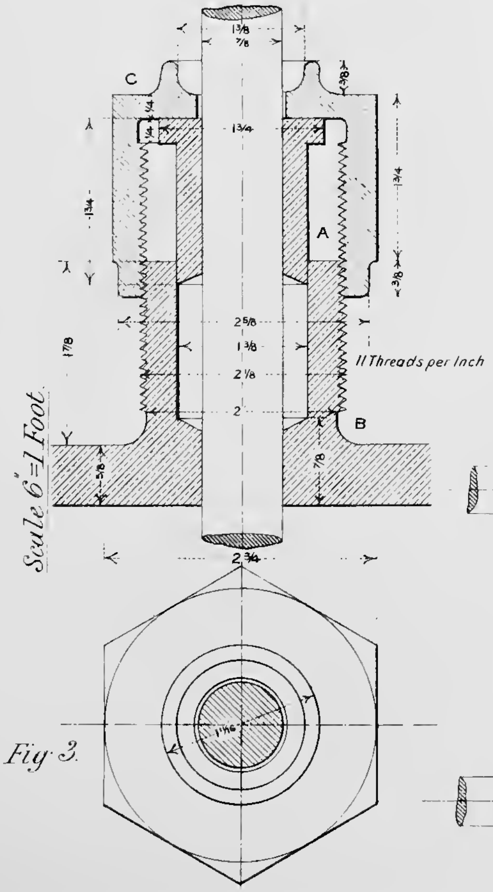


Fig. 2

Scale 3″=1 Foot.

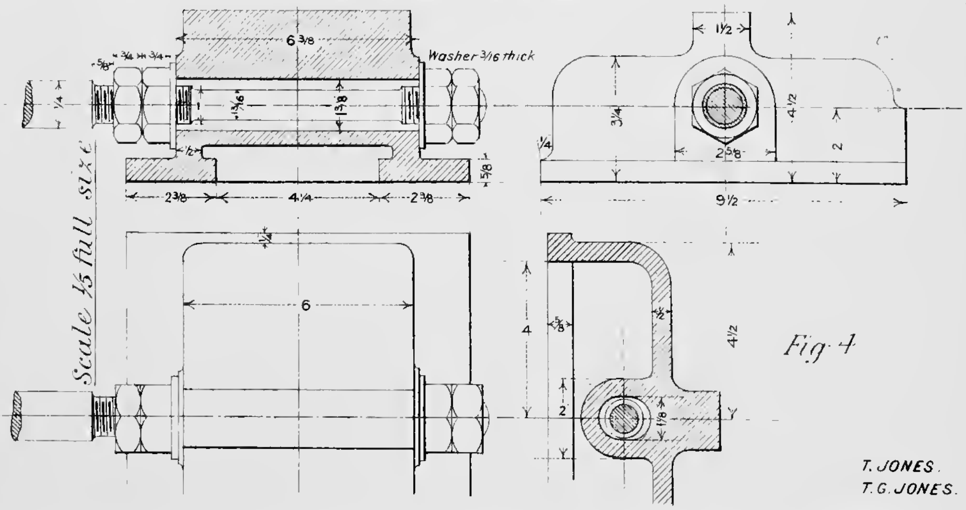
BRASS STUFFING BOX.



Scale 6″=1 Foot.

Fig. 3.

SLIDE VALVE AND SPINDLE.



Scale ⅕ full size

Fig. 4.

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Plate XXX.—CYLINDER FOR HORIZONTAL ENGINE.

THE drawings on the opposite page and the perspective illustration given below, represent the cylinder for a horizontal non-condensing steam engine.

The cylinder is 12″ diameter and the stroke of the piston 19″. The cylinder and steam chest **S** are made in one piece, the material being tough close grained cast iron. Facings are cast on the engine bed to carry the cylinder, which is held in its place by bolts passing through the engine bed and the feet on the cylinder.

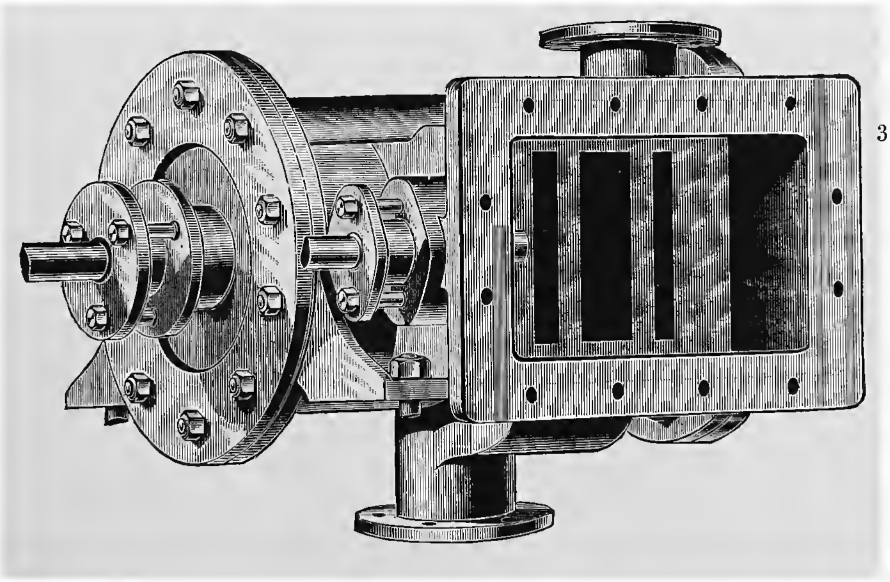
The cylinder is accurately bored to fit the piston, the ends being slightly dished or bell mouthed, so that the piston works a little over the cylindrical part and thus wears the surface evenly. The covers and flanges are turned true and are held together by eight bolts and two stud bolts in each. The stud bolts are used where the steam passages enter the cylinder.

At each end of the stroke a small space is left between the piston and the covers, which is termed the clearance. The distribution of the steam to the cylinder is effected by means of the short **D** slide valve **V**, of which fully dimensioned drawings are given in Fig. 4, Plate XXIX. The back of the valve **V** fits against the inner face of the steam chest cover

This *partially balances* the valve by reducing the pressure, and therefore the friction between the faces of the valve and cylinder. Steam is admitted to the steam chest **S** by the 3″ pipe **M**, cast on the top side. The exhaust steam leaves the cylinder, passes through the slide valve **V**, through the exhaust port, and then round the underside of the cylinder, and out at the 4″ exhaust pipe **N**. For the dimensions of the front cover, slide valve, and valve spindle stuffing box, see Plate XXIX., and for the 12″ piston, see Plate XXVII.

The piston **P** is moved forward by the steam, which exerts a continually *varying* pressure as it expands. The *back pressure* on the opposite side of the piston also varies. The difference between these two pressures in any position of the piston is the *effective* pressure, and the average of these effective pressures is the *mean effective pressure* throughout the whole stroke. The *mean* on the opposite side of the piston is also found, and the average of these two means is the value of P required in the formula for horse-power given below. When an engine is running, the value of P is obtained from an indicator diagram.

To find the horse-power **H** of an engine :—



$$\mathbf{H} = \frac{2\,A\,P\,R\,S}{33{,}000}$$ where A = Area of piston in square inches.

P = lbs. per square inch.
R = Number of revolutions per minute.
S = Stroke of engine in feet.
33,000 = Units of work in one horse-power per minute.

EXERCISE.

Draw the four views of the 12 steam cylinder as given.—*Scale $\frac{1}{5}$ full size.*

QUESTIONS.

1.—Find the horse-power of the 12″ engine, taking P = 60lbs. and R = 120.

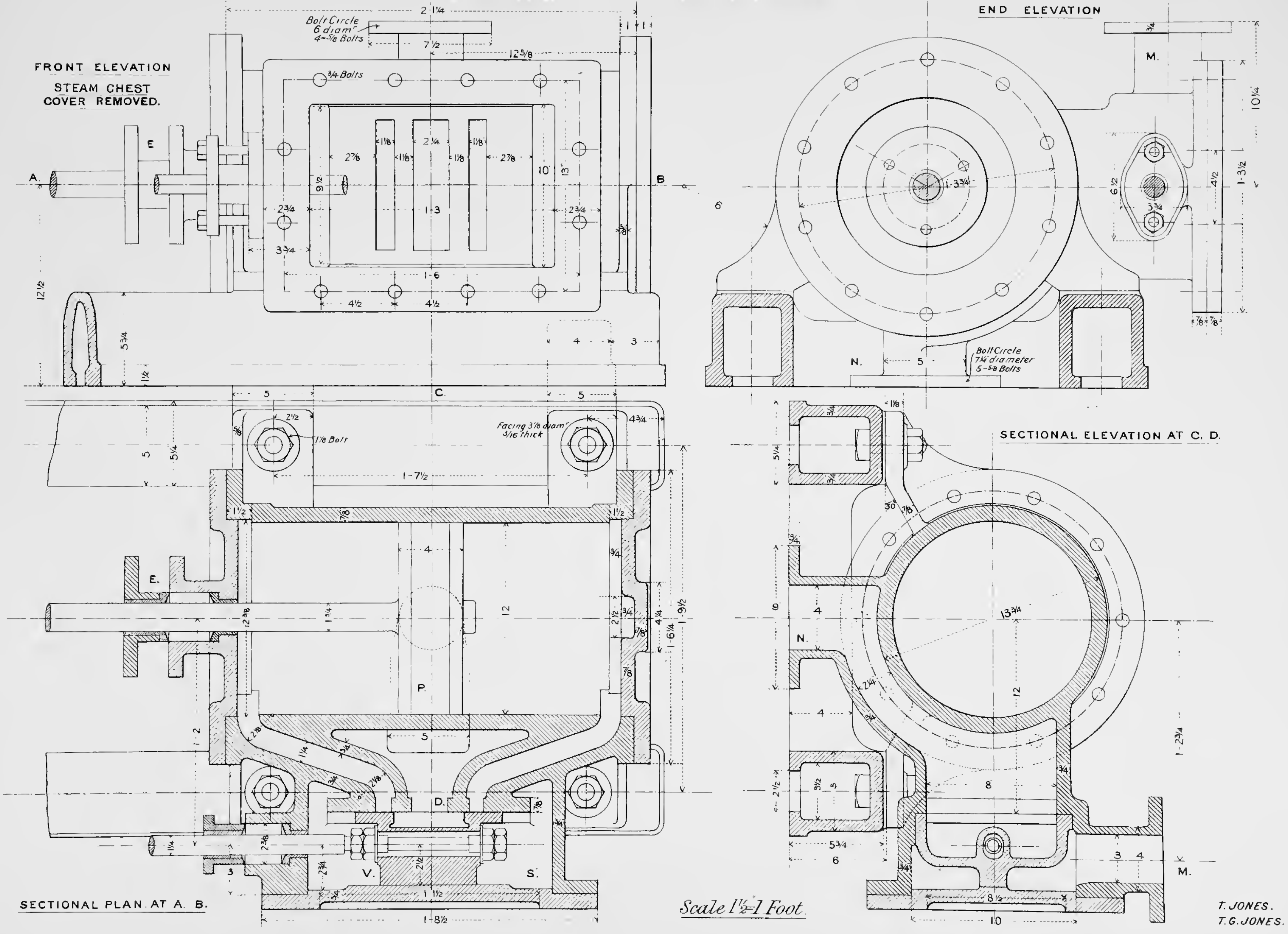
2.—Explain the terms: Travel, steam and exhaust lap, lead, as applied to slide valves.

3.—Find the positions of the crank—(1) When steam is admitted to the cylinder; (2) when cut off; (3) when released; (4) when compressed. Assume that there is no lead.

NOTE.—If the student wishes to understand the action of a simple slide valve in distributing steam, he is advised to study the slide valve models designed by the authors.

PLATE XXX.

CYLINDER FOR HORIZONTAL ENGINE.



Scale 1½″ = 1 Foot.

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Plate XXXI.—MEYER'S VALVE GEAR, &c.

SOME of the disadvantages attending the use of the common **D** slide valve are :—That the pressure of the steam is considerably reduced near the point of **cut-off**, owing to the comparatively slow motion of the valve over the port ; and also, that an early cut-off cannot be effected with it.

To obtain a quicker and variable cut-off, the valve is modified, and a second valve, called the expansion valve, placed on the back of it. This arrangement of valves and the mechanism for actuating them is known as Meyer's Valve Gear, and is very largely used owing to its efficiency and simplicity of action.

***Figs. 1 to 4** show the valves of Meyer's Gear as applied to a horizontal engine. The main or distribution valve **A** differs from an ordinary slide valve, since the steam is not admitted to the cylinder at its outer edges, but through a passage **L** in each end. This valve effects the admission, release, and compression of the steam in the same manner as an ordinary simple **D** valve. It is driven by an eccentric, which is set so that the steam will be cut off by this valve alone, at about $\frac{3}{4}$ of the stroke.

The cut-off is effected by closing the passage **L** with the expansion valve, which passage remains covered until the steam port is closed by the main valve. The expansion valve consists of two cast iron plates **B B**, connected by a right and left hand screw on the spindle **D**, which is actuated by a second eccentric on the crank shaft. Any rotation of **D** will either increase or diminish the distance between the two plates. The expansion valve, therefore, forms a plate which may be either lengthened or shortened, and by means of which an earlier or later cut-off will be obtained. In order that the variation of expansion may be effected during the running of the engine, the spindle **D** passes through the back of the steam chest and a fixing **E**. A length of 10 inches on the end of **D** is of square section, and passes through a long brass screw **F**, to which is fixed a hand-wheel **H**. The spindle is therefore allowed a reciprocating motion, and at the same time may be turned round by the hand wheel. A circular nut **H** with a pointer is placed on the screw **F**, so that the cut-off taking place in the cylinder may be observed.

Figs. 7-8-9 show a double ported slide valve as used for distributing the steam to the low pressure cylinders of marine engines. Each steam passage has two ports in the cylinder face of about half the area of the steam passage. Steam is admitted simultaneously to the cylinder through the two ports, so that for a given travel of the valve, twice the area of the steam port is uncovered as in an ordinary **D** valve. The exhaust steam, which leaves the cylinder by the *outer* steam port, passes through the body of the valve, and through the exhaust port in the cylinder face, as shown in Figs. 8 and 9.

EXERCISES.

1.—Show the main valve **A** and rod, by means of the following views :—Back elevation, two sectional plans, end, and sectional end elevations. *Scale 4″ = 1 foot.*

2.—Draw one expansion plate B as given in Figs. 1, 3 and 4. *Scale 4″ = 1 foot.*

3.—Draw the bracket **E**, showing sectional elevation and plan, and end elevation, looking at the hand wheel end. *Scale ½ full size.*

4.—Draw the various views of the Meyer's valves and adjusting bracket as given. *Scale 3″ = 1 foot.*

5.—Draw the three sections of the double ported valve as given, and add front and end elevations and a plan. *Scale 3″ = 1 foot.*

6.—Show, by means of a sketch, how the double ported valve may be partially balanced by a relief ring placed at the back.

*See the slide valve models designed by the Authors.

PLATE XXXI.

MEYER'S VALVE GEAR FOR HORIZONTAL ENGINE.

Scale 1¾″ = 1 Foot.

BACK ELEVATION OF VALVES.

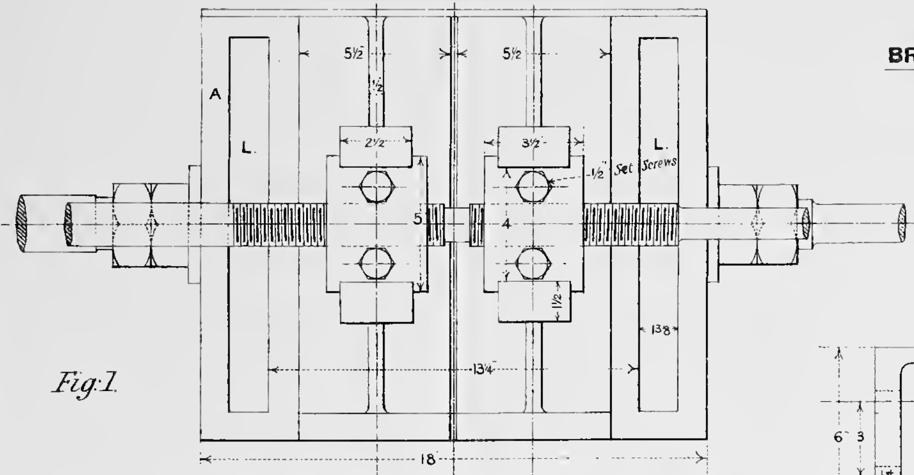

Fig. 1.

BRACKET TO CARRY REGULATING SCREW.

SECTIONAL ELEVATION

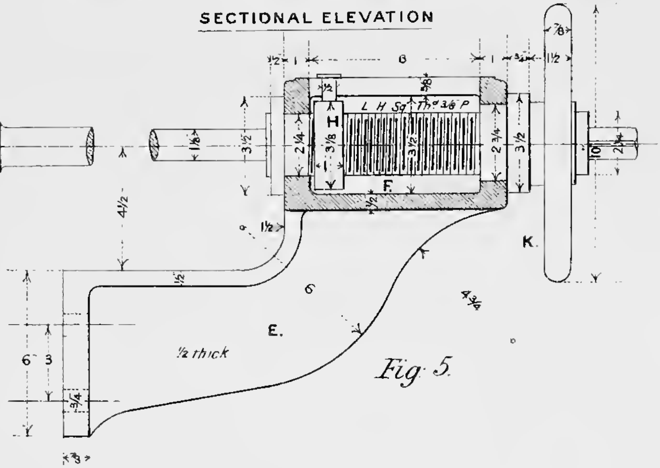

Fig. 5.

END ELEVATION OF VALVES.

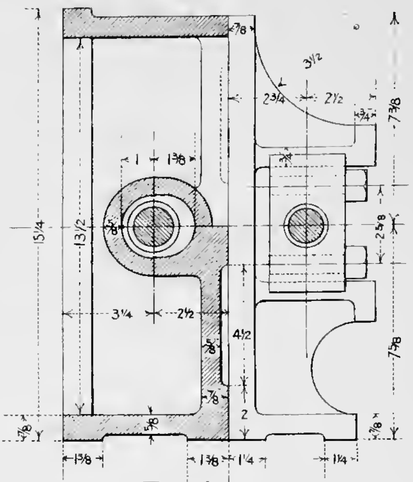

Fig. 4.

SECTIONAL PLAN OF VALVES.

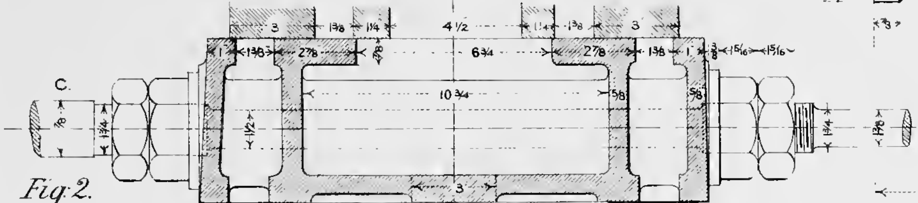

Fig. 2.

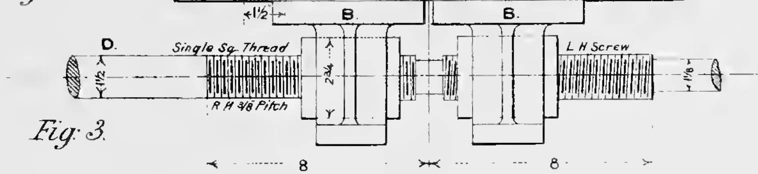

Fig. 3.

SECTIONAL PLAN OF BRACKET.

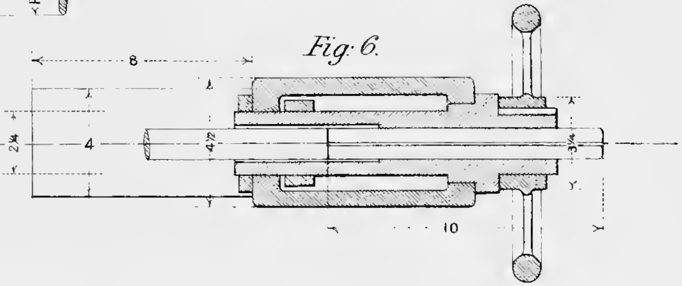

Fig. 6.

DOUBLE PORTED SLIDE VALVE.

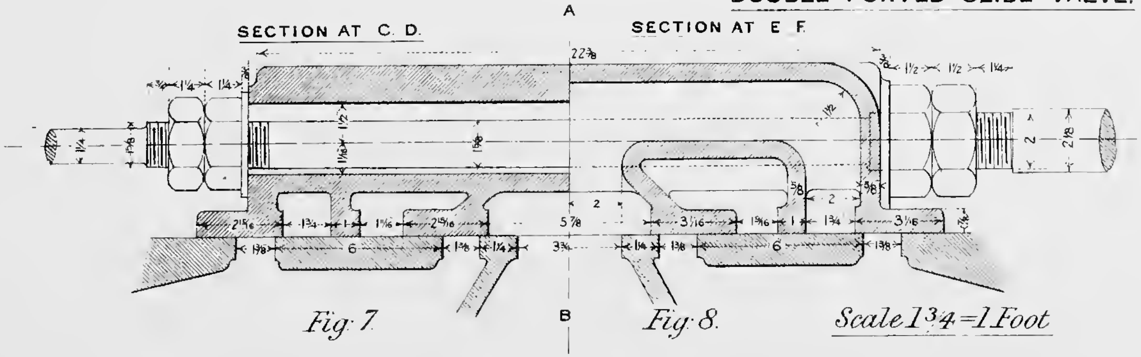

Fig. 7. *Fig. 8.*

Scale 1¾ = 1 Foot

SECTION AT A. B.

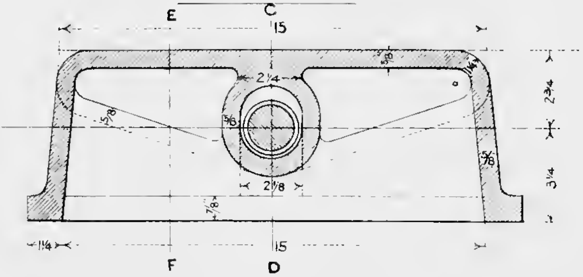

Fig. 9.

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Plate XXXII.—STEAM STOP VALVE.

THE drawing shows a 3″ stop valve as used to regulate the supply of steam to the cylinder of a steam engine, and for other purposes where steam is employed.

The cast-iron body **C** of the valve is barrel-shaped and provided with two parallel flanges on the ends, for connecting it to the 3″ pipes used for conveying the steam. There is also a flange on the top, to which the cast iron cover **D** is bolted.

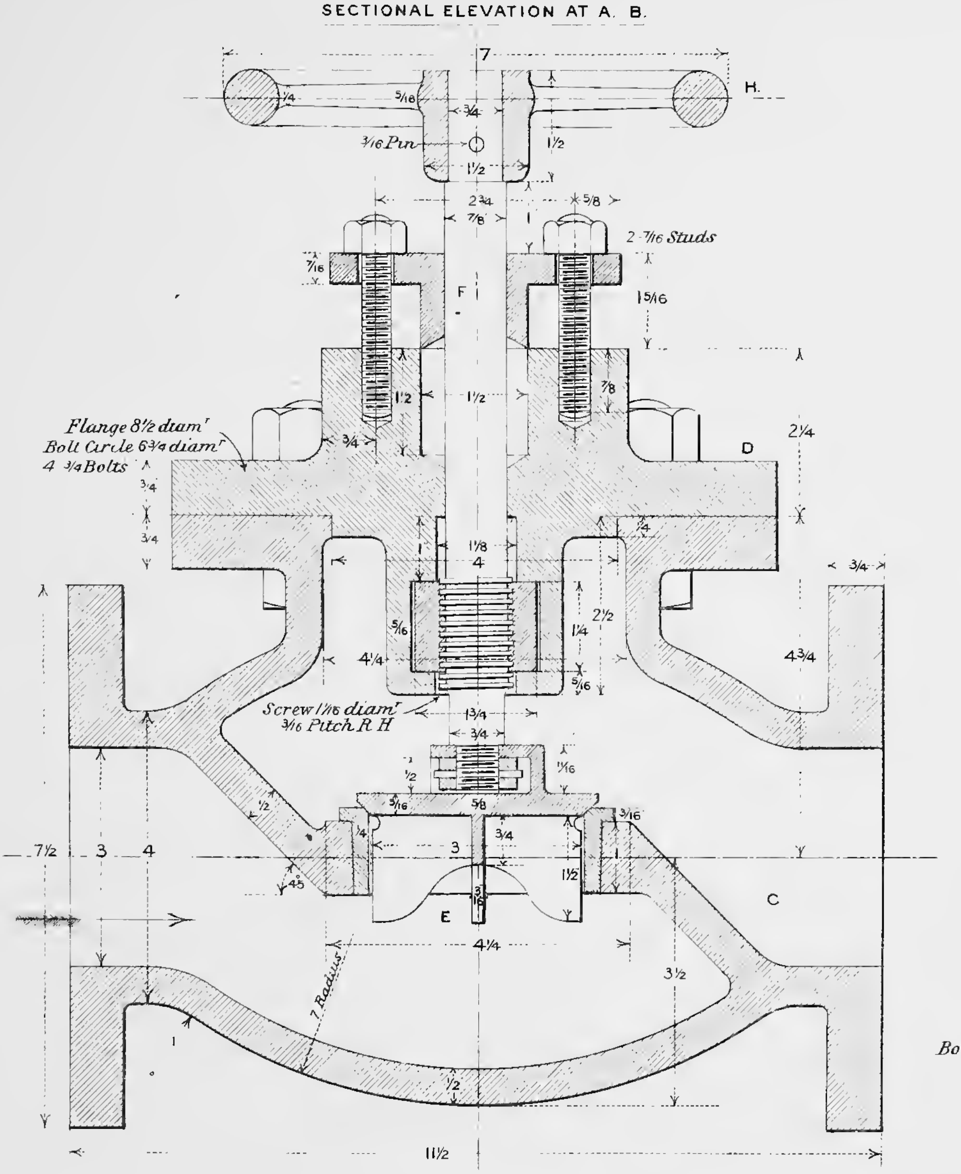
The body is divided into two compartments by a web. The horizontal portion of the web is cored out for the passage of the steam. This part is bored, and fitted with a brass seating, into which seating, a brass valve or clack **E** rests. The brass clack has four wings cast upon it to guide it as it rises and falls in the seating. The brass screw **F**, which works through a brass nut fixed in a recess in the cover, regulates the lift of the clack. It is connected by a loose collar to the top of the clack. The cover **D** carries a stuffing box and gland, through which the end of the screw passes, a steam tight joint being made as before described. The screw is turned by a cast iron hand wheel **H** attached to the top end by means of a round pin. The steam enters the valve on the underside of the clack **E**, passes through the seating and out through the opposite side of the valve.

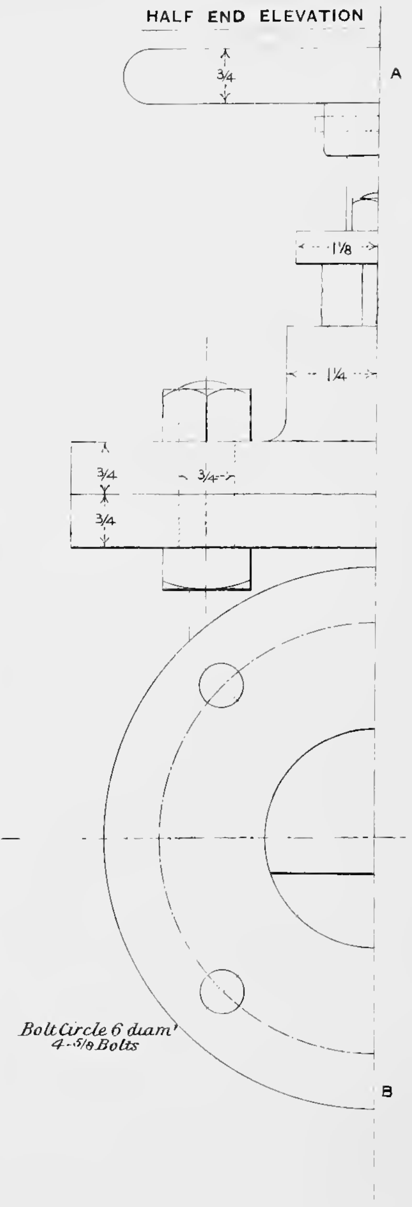
The screw therefore, by holding the clack firmly on its seating, keeps the valve steam tight, and there is no pressure on the cover **D** when the valve is closed.

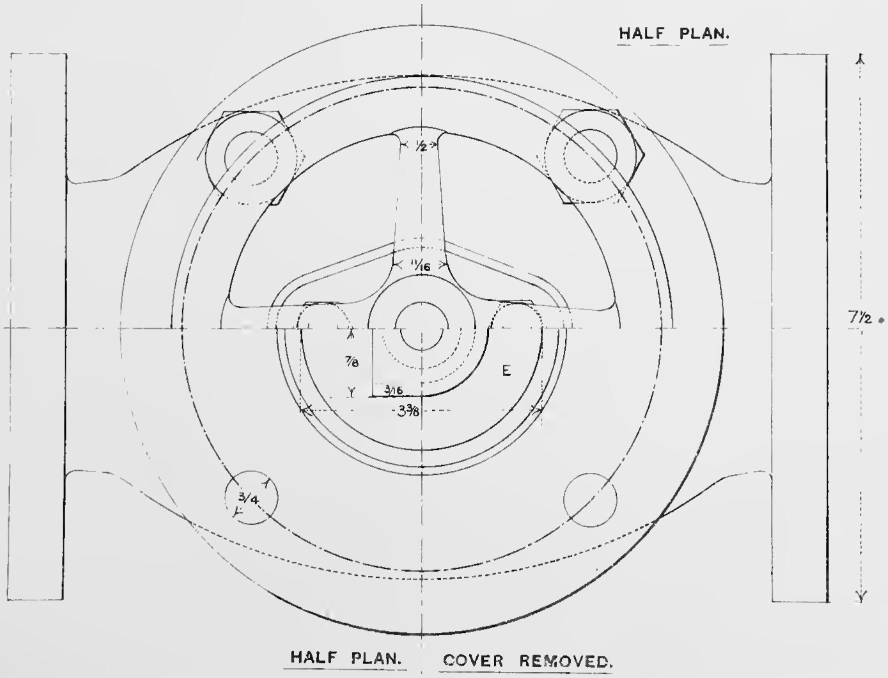
EXERCISE.

Draw the 3″ steam valve to the dimensions given, completing the end elevation. *Scale 8″ = 1 foot.*

PLATE XXXII







STEAM STOP VALVE.

FOR 3″ PIPE.

Scale 3/8 full size.

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Plate XXXIII.—PUMP VALVES OR CLACKS.

VALVES or clacks, as they are often termed, are used in pumps of various kinds, and sometimes in stop valves, as shown in Plate XXXII.

In pumps for water they allow the water to pass from one part of the pump to another. In one stroke of the pump the water presses on the underside of the clack, opens it, and passes to the top side. In the return stroke the pressure comes on the top of the clack, which drops into the seating and thus prevents the return of the water.

In a single acting pump two clacks are required, one on the **suction** side and the other on the **delivery** side.

In a double acting pump two of each are required. They are termed respectively suction and delivery clacks. They are made of various forms, several of which are given in the drawings.

Figs. 1 and 2 are simple drop clacks, the only difference being in the method of guiding them to the seating. They are both made of brass as well as the seatings upon which they rest. In Fig. 1 the clack **A** is guided by the three wings cast on the lower side; the joint being made by the conical edge fitting the conical seating **B**. These are turned and then ground to fit exactly. In Fig. 2 the clack **A** is guided by the round pin fitting the boss in the centre of the seating. The *clear* lift of the clack should be ¼ the diameter of the seating in order to give the full area for the passage of the water.

Fig. 3. In this form, which is made entirely of brass, the ball **A** is the clack, and the piece **B** the seating. A guard **C**, which prevents the ball from lifting too high, is screwed to the seating.

Fig. 4.—The india rubber disc is chiefly used in air pumps, the same form being employed for the pump buckets.

It is sometimes used for large pumps, but is not suitable for a high lift or a great pressure, since the disc is forced into the holes in the seating and is soon destroyed.

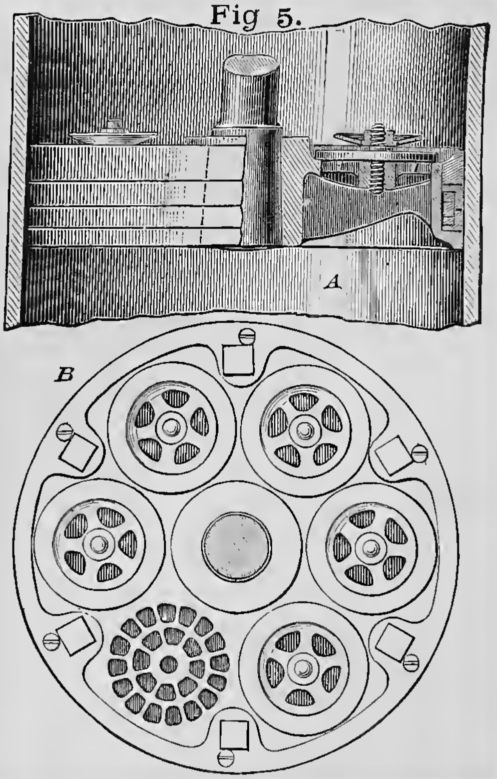
A is an india rubber disc resting on the brass seating **B**, and **C** is a brass guard which prevents the disc from lifting too high or bending too much. The guard and seating are held together, and the whole secured to the cast-iron clack plate, by the brass bolt and nut and the wrought-iron crossbar. The seating has a series of small openings cast in it, forming a grid. This is done to distribute the bearing surface for the disc and prevent the water forcing it through the openings.

The annexed illustration, Fig. 5, shows a sectional elevation and plan of a Marine air pump bucket of large diameter.

There are a group of six india rubber disc clacks placed on the top side of the bucket, each fitted as shown in Fig. 4.

The packing of the bucket is of the "Mather and Platt" type, as shown in the piston, Plate XXVII.

Fig 5.



EXERCISES.—*To be Drawn Full Size.*

1.—Draw the two conical clacks, as shown in Figs. 1 and 2, adding a plan of the first one.

2.—Draw completely an elevation, a sectional elevation, and a plan of the ball clack, Fig. 3.

3.—Draw the elevation and section of the clack given in Fig. 4. Show half plan of the guard, &c., and half plan of the seating.

SIMPLE VALVES FOR PUMPS.

CONICAL VALVES.

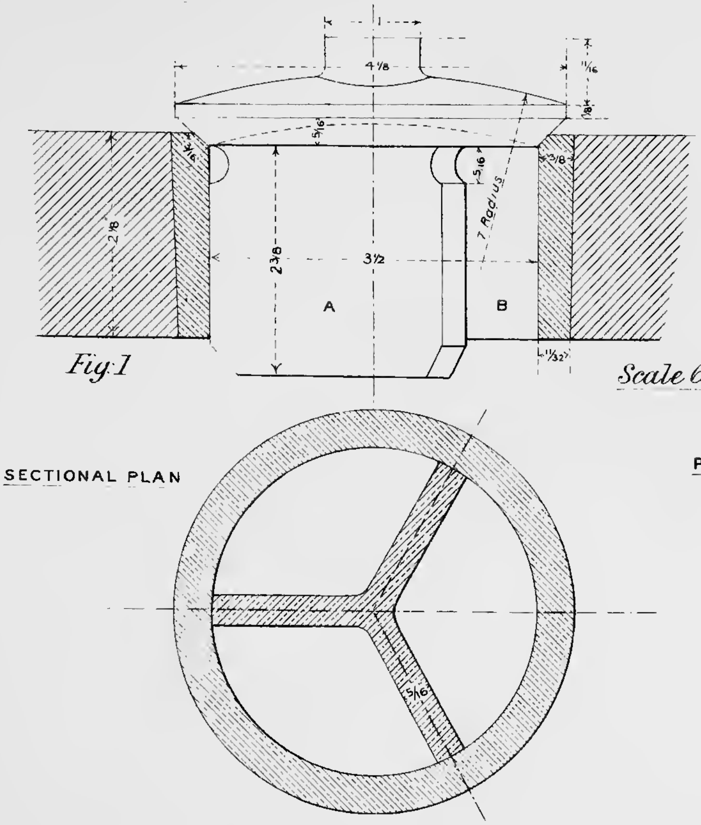


Fig. 1

Scale 6" = 1 Foot.

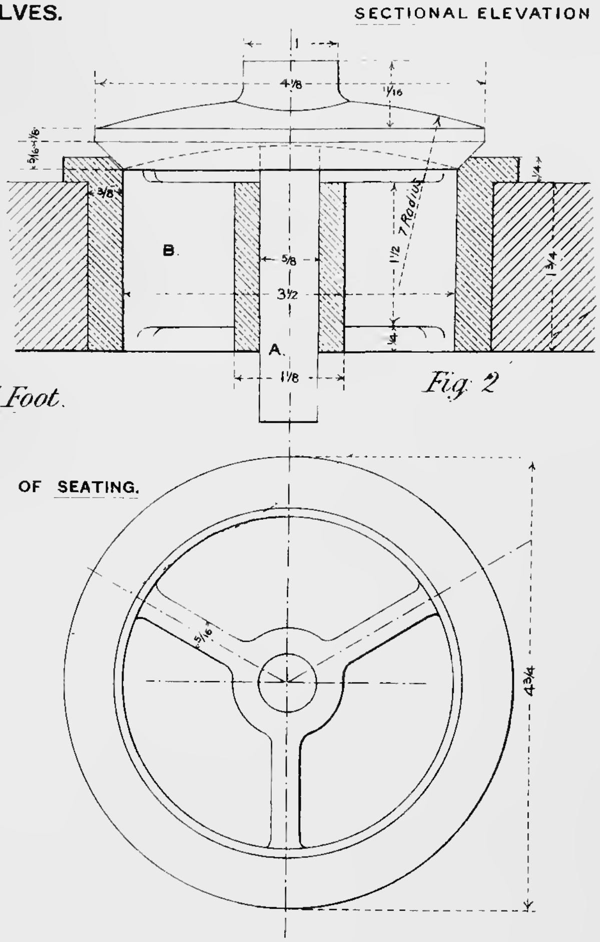
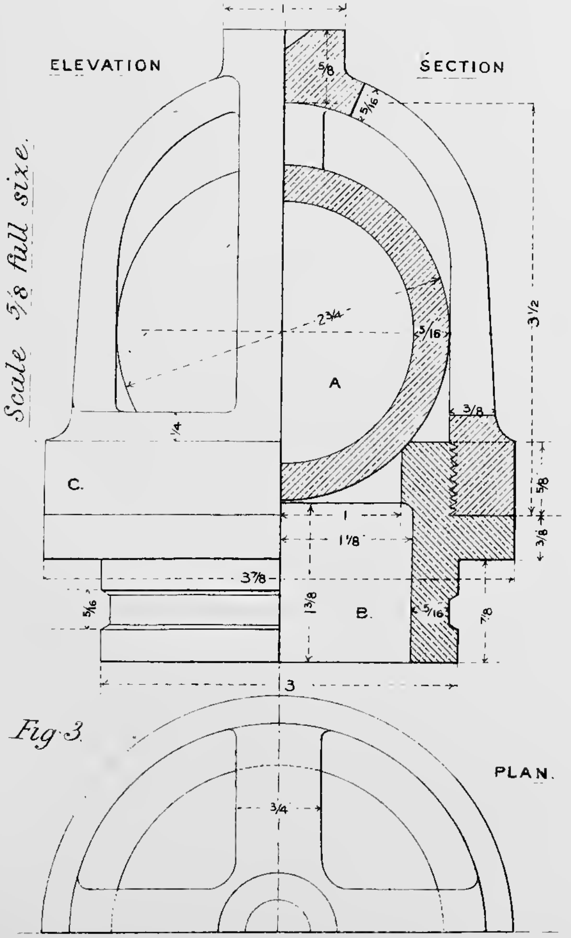


Fig. 2

BALL VALVE.



Scale ⅝ full size.

Fig. 3.

INDIA RUBBER DISC VALVE.

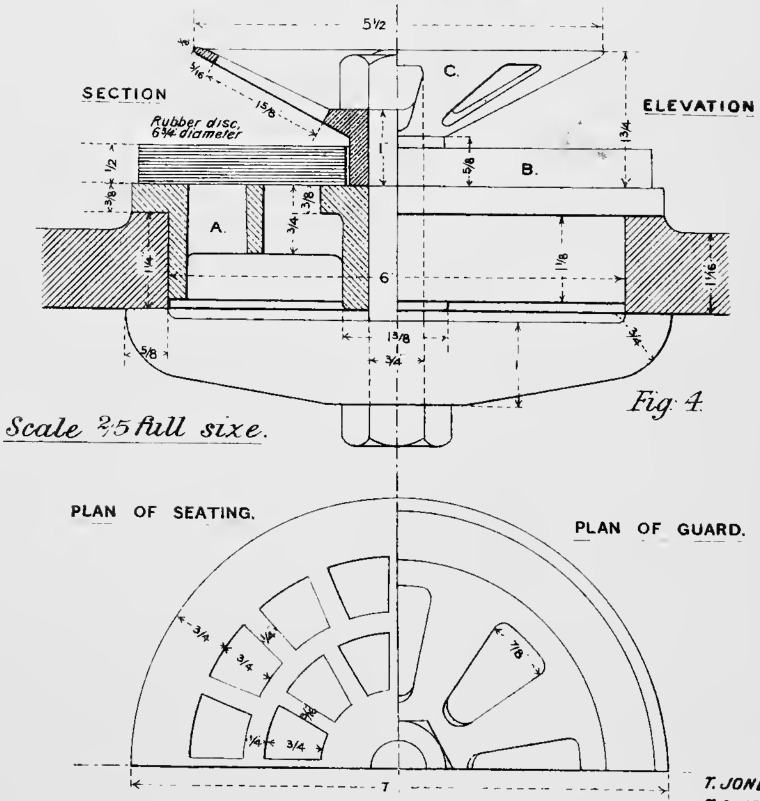


Fig. 4.

Scale ⅖ full size.

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Plate XXXIV.—LOOSE HEADSTOCK FOR 8″ LATHE.

THE **Loose Headstock** of a lathe serves to carry one of the centres, between which the work to be operated upon, rotates. The other centre is carried by the **Fast Headstock,** which is fastened permanently to the lathe bed. See Plate XXXV. Since the distance between the centres is to be adjustable, to suit the various sizes of work, the loose headstock is movable along the bed, to which it can be firmly bolted in any position.

The drawings on the opposite page, and the illustration given below, show a loose headstock as used for heavy work. The base is planed, and the two projections made to exactly fit the space between the faces of the bed, so that the headstock can be moved along it in a straight line. Three long steel bolts, passing through the body and into cast iron clamps **K K**, serve to fasten the headstock down, in any required position.

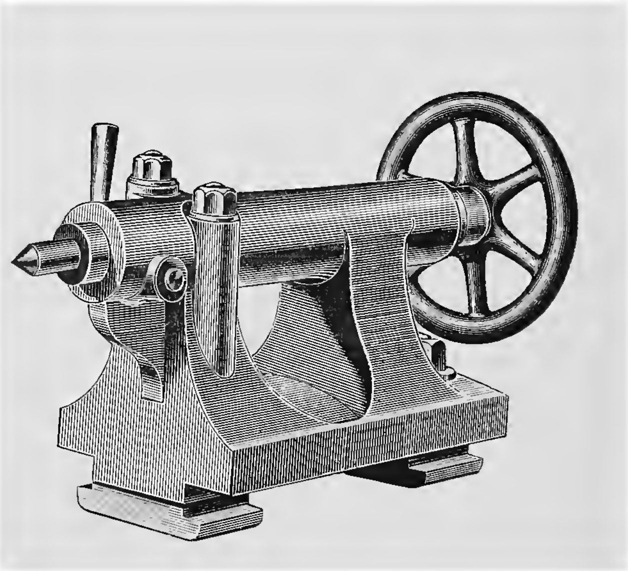
The body of the headstock is cast hollow, and a hole bored through it, along which the steel barrel **D**, carrying the cast steel centre, can be moved by the hand wheel **H** and steel screw **F**. The front end of the barrel is coned to receive the centre, and the other end forms a nut for the screw.

The screw has only a motion of rotation, since it turns between two shoulders; the boss of the handwheel forming one, and the other being forged on the screw.

The handwheel **H** is fastened to **F** by a square key and a nut. A keyway is cut on the underside of **D**, so that it can slide along a fixed **T** headed key and not rotate.

The screw is made of such a length, that when the barrel **D** is almost entirely in the headstock, the end of it butts against the centre, and any further rotation of the screw would displace it.

The barrel can be locked in any position by tightening up the handle **L** on the round bolt, which passes under the barrel, and is shaped to fit it.

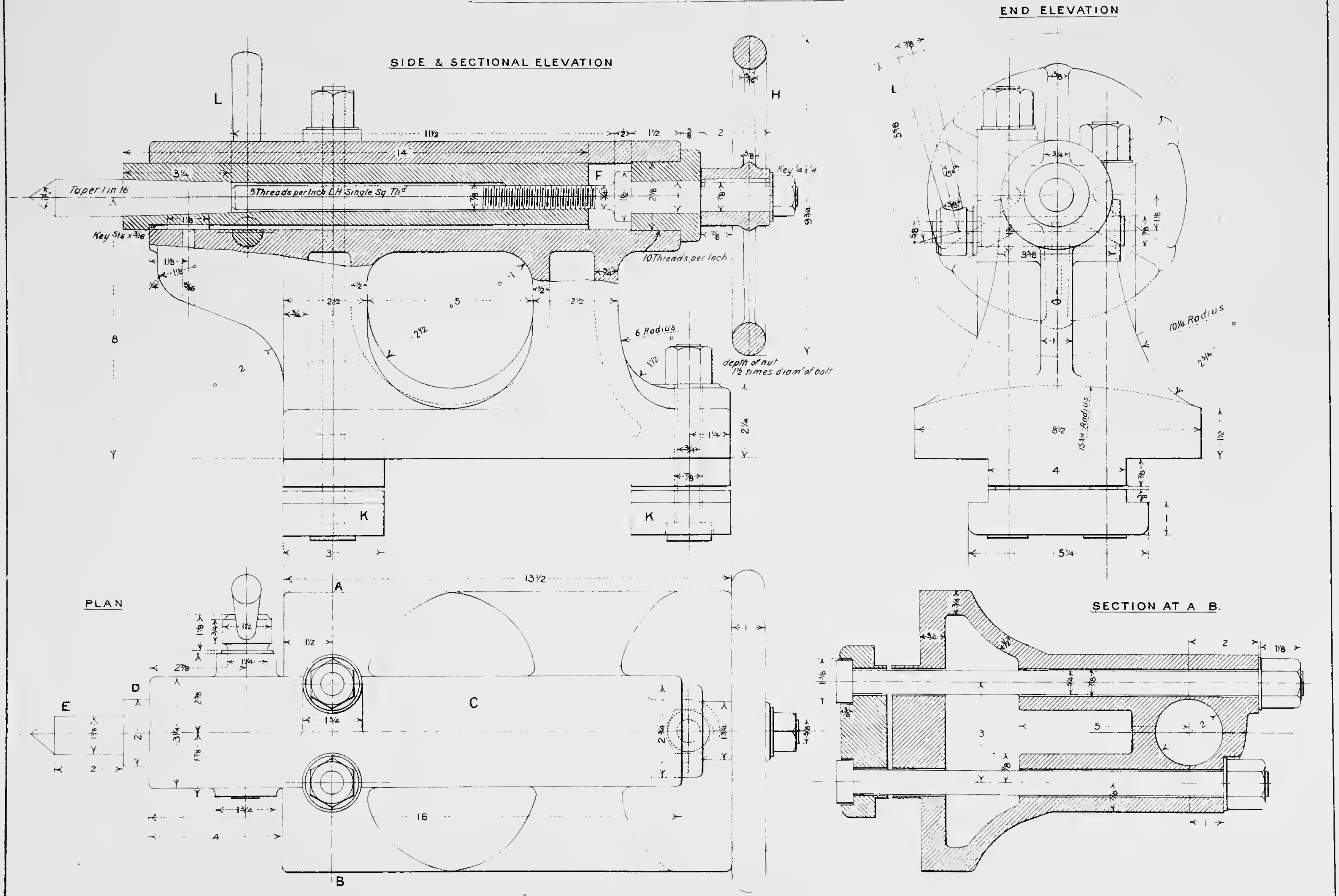


EXERCISE.

Draw the four views of the headstock as given, and add a cross section through the opening between the two uprights. *Scale $\frac{3}{8}$ full size.*

NOTE.—The elementary student should be given, as exercises, various details of this headstock to draw to suitable scales. He will feel much more interest in the work when he sees the exact position and use of the piece he is drawing. This remark applies to most of the examples given throughout the book.

LOOSE HEADSTOCK FOR 8" LATHE.



Scale 3"=1 Foot.

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Plate XXXV.—FAST HEADSTOCK FOR 8″ LATHE.

FIGS. 1-2-3 show a back geared fast headstock for an 8″ lathe, and **Figs. 4-5-6** give enlarged details of some of its parts.

The base of the body **E** is planed and provided with two projections, which exactly fit the groove in the bed, and thus keep the spindle **H** parallel with the top and sides of it. It is secured by four screws which pass into clamping pieces on the under side of the bed.

The steel spindle **H** is supported in the headstock by two conical steel bushes. The front bush is fitted tightly into the hole, while the other one is held lengthways by two thin circular nuts **M M**. An adjustment for the wear of the spindle and the bushes can be made by the nuts **M M**, and lock nuts **N N**. Conical bearings have an advantage over cylindrical ones, since the centre of the spindle always remains at the same height above the lathe bed.

The end thrust on the spindle is transmitted through the washers **P** to the crossbar **K**, which is fixed on the ends of two pillars by nuts.

The cone pulley **F**, to which the pinion **C** is fastened, runs loose on the spindle, but may rotate with it if **C** be in gear with the spur wheel **A**. For the method of connecting **A** to **F**, refer to Figs. 1 and 5. The cone plate is secured to the pulley by six $\frac{3}{8}''$ screws. The front end of **H** has a conical hole bored in it to receive the cast steel centre. It is carefully fitted to the hole, and the end afterwards turned up in its place when the lathe is complete.

In plain bearings, in the sides of the headstock a shaft **L**, is placed parallel to **H**, upon which revolves a hollow cast iron shaft, having keyed to its ends, the spur wheel **B** and the pinion **D**.

B and **D** can be put in or out of gear with **C** and **A** respectively, by turning the shaft **L** through half a revolution, since its ends are eccentric with the portion upon which **B** and **D** revolve. A collar is pinned on the right hand end of **L**, and is fitted with two small handles, as shown in Fig. 6, by means of which **L** is rotated. A segment cast on the arm of the headstock prevents the handles being moved through more than 180°.

EXERCISE.

Draw the three given views of the fast headstock and add another end elevation. *Scale 3″ = 1 foot.*

QUESTIONS.

1.—Suppose the cone pulley on the headstock to be driven from one of the same size on a counter-shaft making 150 revolutions per minute. Determine the various speeds of the spindle which can be obtained, with and without back gearing.

2.—Give sketches, showing how you would grip and drive a round iron bar for the purpose of turning it between the centres of a lathe.

NOTE.—The elementary student should be given, as exercises, various details of this headstock to draw to suitable scales. He will feel much more interest in the work, when he sees the exact position and use of the piece he is drawing. This remark applies to most of the examples given throughout the book.

FAST HEADSTOCK FOR 8" LATHE

PLATE XXXV.

Scale 1/6 full size.

SECTIONAL & SIDE ELEVATIONS.

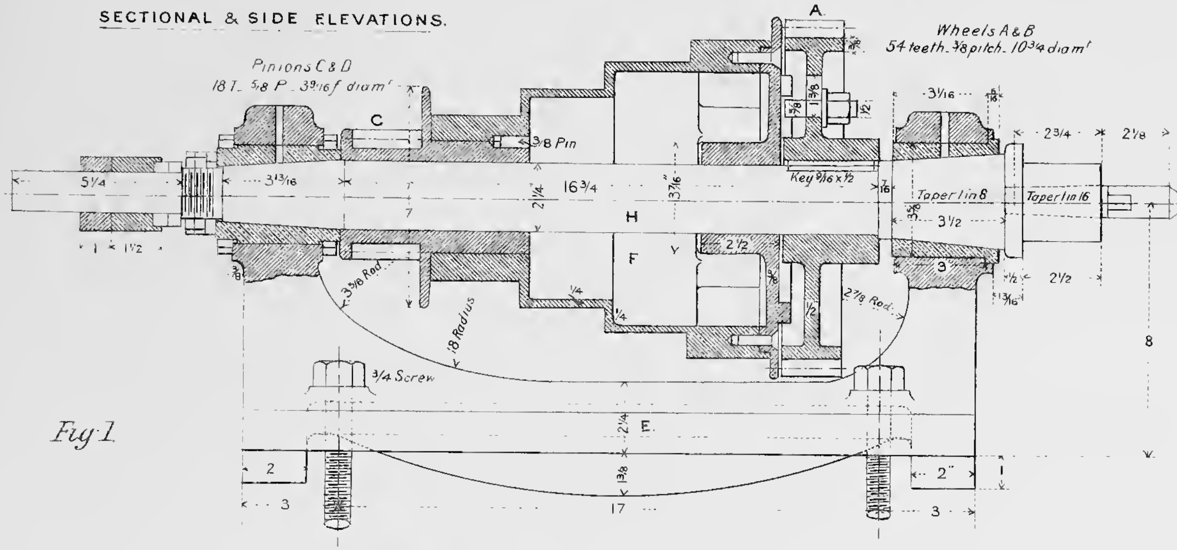

Fig. 1.

END ELEVATION

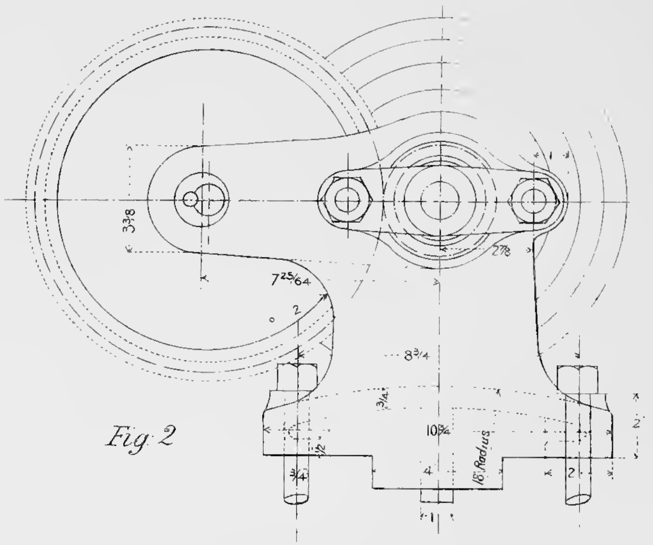

Fig. 2

PLAN

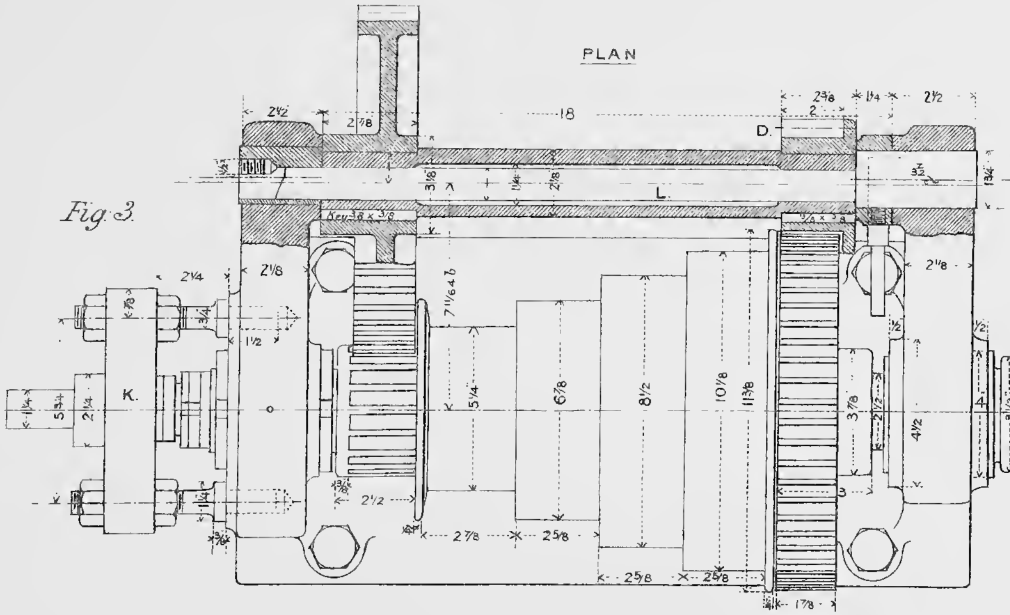

Fig. 3.

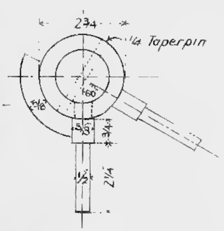

Fig. 6

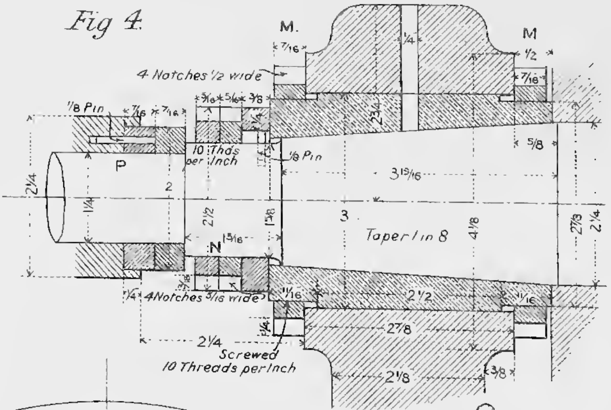

Fig. 4.

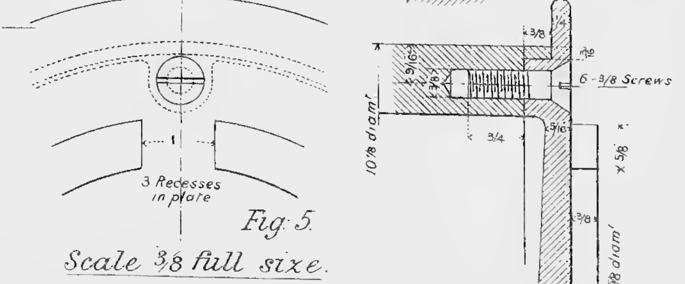

Fig. 5.

Scale 3/8 full size.

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Plate XXXVI.—16″ JAW CHUCK FOR LATHE.

A JAW chuck is used for the purpose of holding or *chucking* work in a lathe, either for turning or boring. It has the advantage of enabling the workman to fix the work easily and quickly, and admits of adjustment when the part operated upon is not concentric with the outer portion by which it is held. The chuck is made in the form of a face plate with sliding jaws, each capable of radial motion. The jaws are stepped, so that work of various diameters can be held by moving them a short distance.

The drawing on the opposite page gives a portion of each of four views of a jaw chuck 16″ diameter. The body **A** is made of cast-iron, and the jaws **B**, the screw **C** and the nuts **D**, of steel.

The screws, which are turned by the box key, have left-hand threads cut upon them. The force due to the holding of the work in the jaws is taken up by the steel collars **E**, which are held in position by round steel pins.

The shanks of the jaws **B** slide in radial grooves, and are tapped for the screws to work through, and the jaws are locked in any desired position by the steel nuts and washers.

EXERCISES.

1.—Make complete working drawings, *full size*, of the following details of the jaw chuck. (1) A cast steel jaw, with locking nut at the back. (2) One of the screws. (3) The box key.

2.—Draw and complete the various views of the jaw chuck as given, and add a plan. *Scale 6″ = 1 foot.*

PLATE XXXVI.

16" JAW CHUCK.

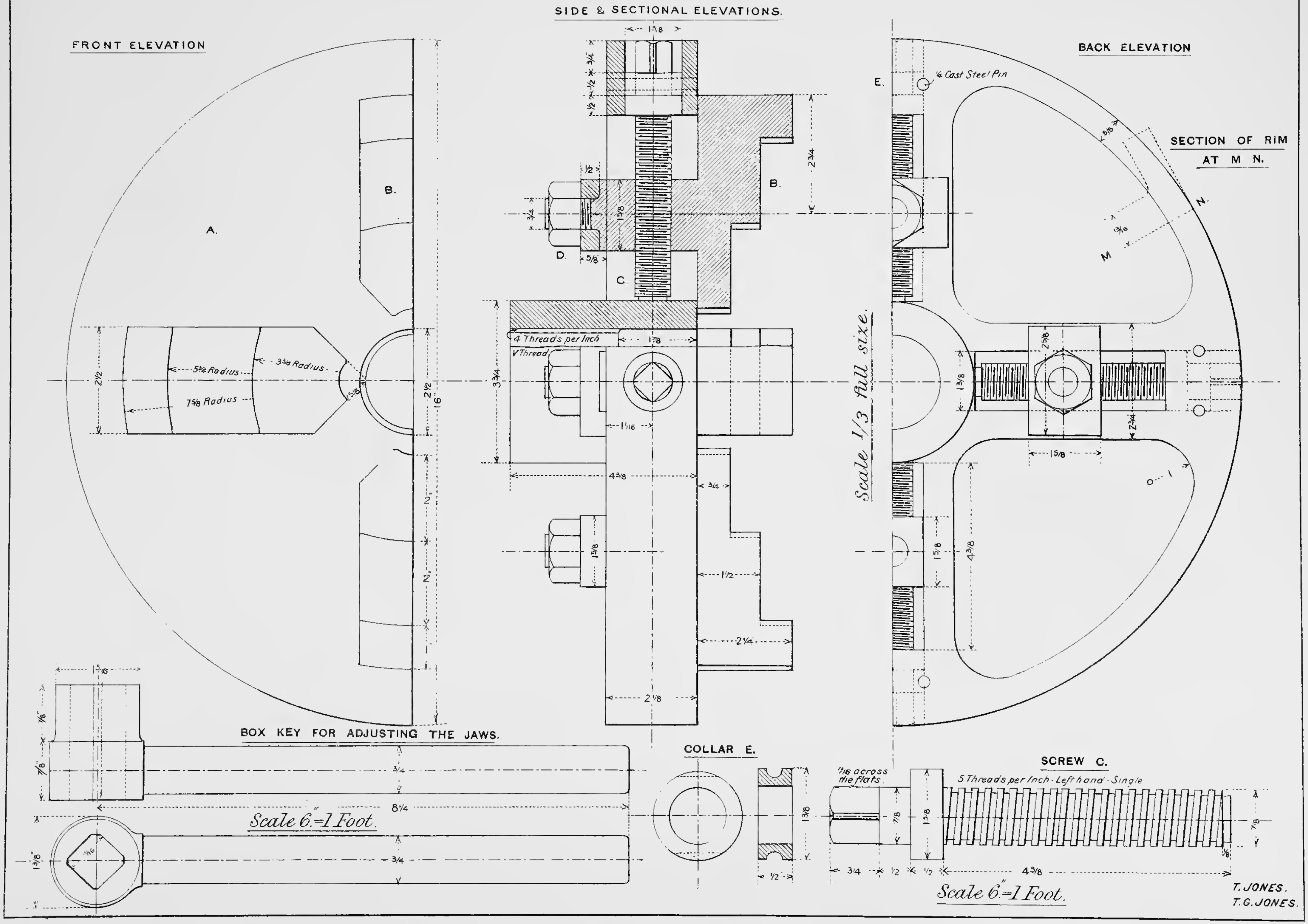

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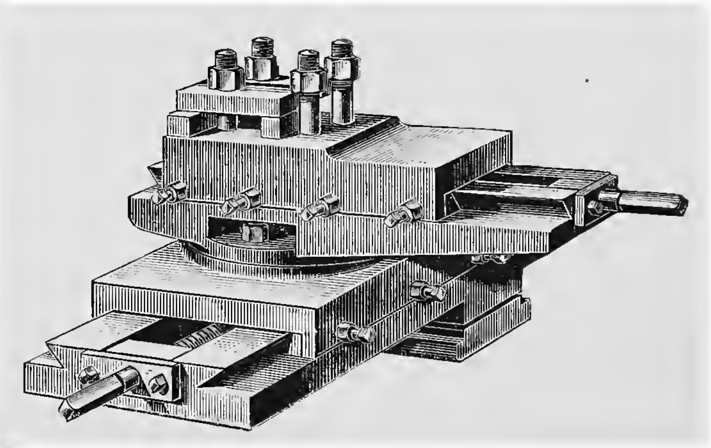
Plate XXXVII.—COMPOUND HAND SLIDE REST.

THE slide rest, shown on the opposite page and in the accompanying illustration, is one which cannot be connected to the guide screw, but must be moved along the lathe bed, by hand. For this reason, it is called a hand slide lathe rest. It is made up of four cast-iron slides **D**, **F**, **G** and **H**. The bottom slide, or saddle **D**, has a projection on the underside, which is planed to fit exactly the groove between the faces of the lathe bed. A good fit is absolutely necessary, in order that the cross motion of the tool may always be at right angles to the length of the bed. **D** is held down to the lathe bed by a screw, which fits into the clamping piece **E**. The top of **D** is provided with two horizontal faces at right angles to the bed, the outer edges of which are planed at an angle of 50° with the top face. The base of the second slide **F** is planed to fit the top of **D**, along which it slides.



A steel screw **L**, supported at one end by the saddle **D**, passes through a brass nut in **F**, and gives motion to **F** in a direction at right angles to the centre line of the lathe.

The brass nut is turned to fit a hole in **F**, and is secured by a small screw.

The slide **G** rests on the top of **F**, on a circular facing, and has a pin cast on its base, about which it can rotate. It is held down by two bolts, which fit in a circular recess in **F**. This enables the slide **G** to be fixed at any angle with the slide **F**. The top slide **H**, which carries the tool, is fitted to **G**, and moved by a steel screw in the same way as the slide **F** is fitted to **D**. The tool is held securely to **H** by the steel bolts **K**, and cross bars.

The motion which can be given to the tool is compounded of two simple rectilinear motions, hence the name of compound slide rest.

All the sliding surfaces are accurately planed and scraped. Since the efficiency of a slide rest depends upon the rigidity of the tool, means must be provided for adjusting the working parts for wear. This is effected in the case of the slides as shown in Figs. 5 and 6. The thrusts along the screws, due to the pressure with which the tool is held against the work, is taken up by the collars and plates, as shown at **C** in Fig. 4, and in the other views.

EXERCISES.

1.—Show, by various views, the top slide **H** of the slide rest. *Scale* 9″ = 1 *foot.*

2.—Draw two elevations, a plan, and longitudinal and transverse sectional elevations, of the slide **G**, showing the screw. *Scale* ⅜ *full size.*

3.—Show the slide **F** and nut, by sectional and side elevations and plans. *Scale* 6″ = 1 *foot.*

4.—Draw the given views of the saddle **D**, and the screw **L**, and add a sectional end elevation. *Scale* ⅜ *full size.*

5.—Draw the given views of the complete slide rest. *Scale* 4″ = 1 *foot.*

QUESTIONS.

1.—Give sketches, showing how the cutting tool of a lathe, or other machine, is secured in its place.

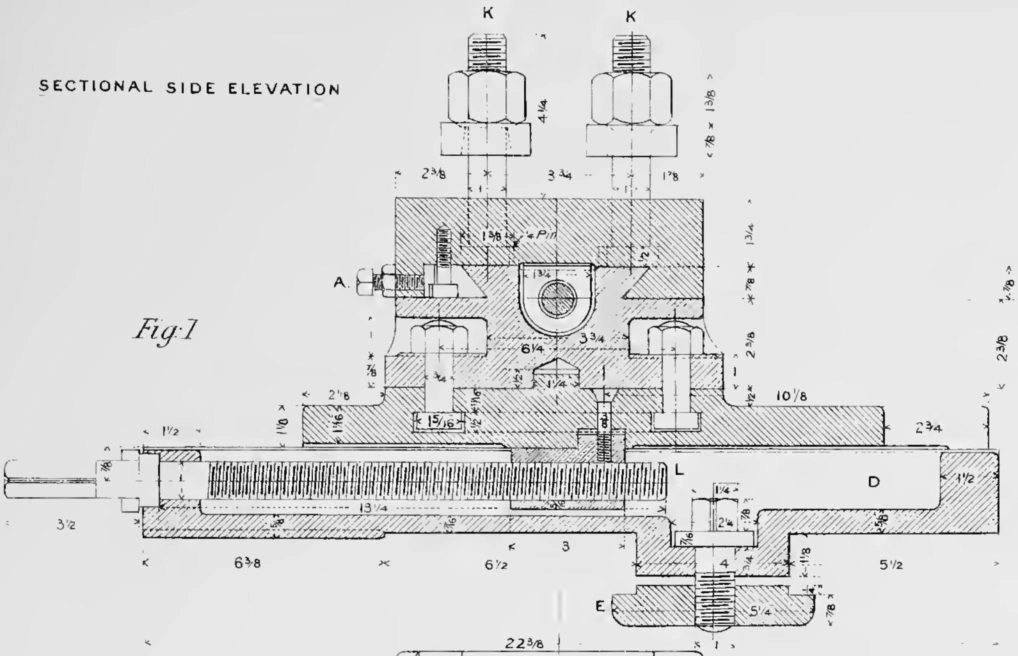
2.—Sketch and describe a simple form of slide rest for a lathe.

3.—Make a sketch showing how the adjustment is made in the sliding parts of machine tools, as, for example, in the slide rest of a lathe.

4.—By sketches and a description, show the construction, by means of which the slide rest of a lathe may be set at an angle for the purpose of turning a taper rod. Explain why the cutting edge of the tool should be placed at the exact height of the axis of rotation, in order to form a portion of a true cone.

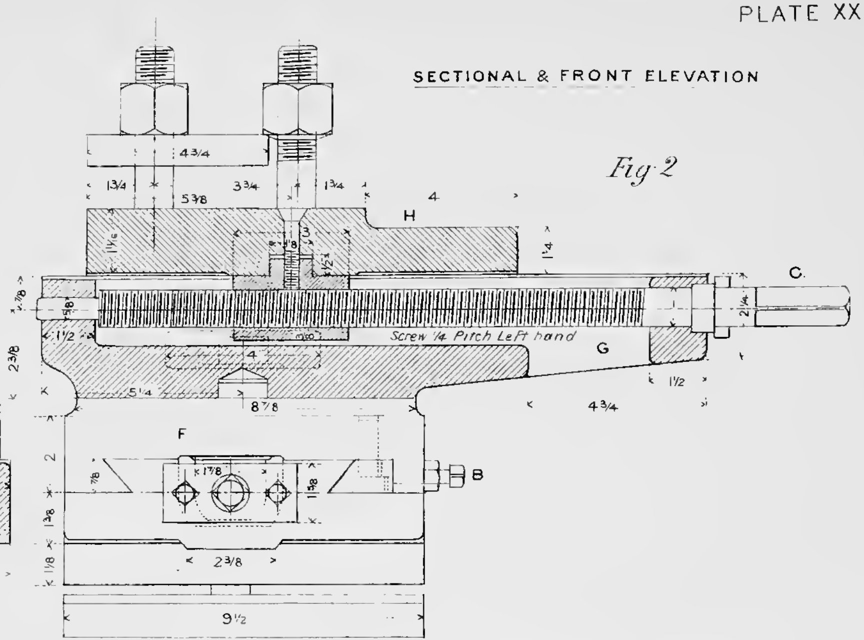
SECTIONAL SIDE ELEVATION

Fig. 1



SECTIONAL & FRONT ELEVATION

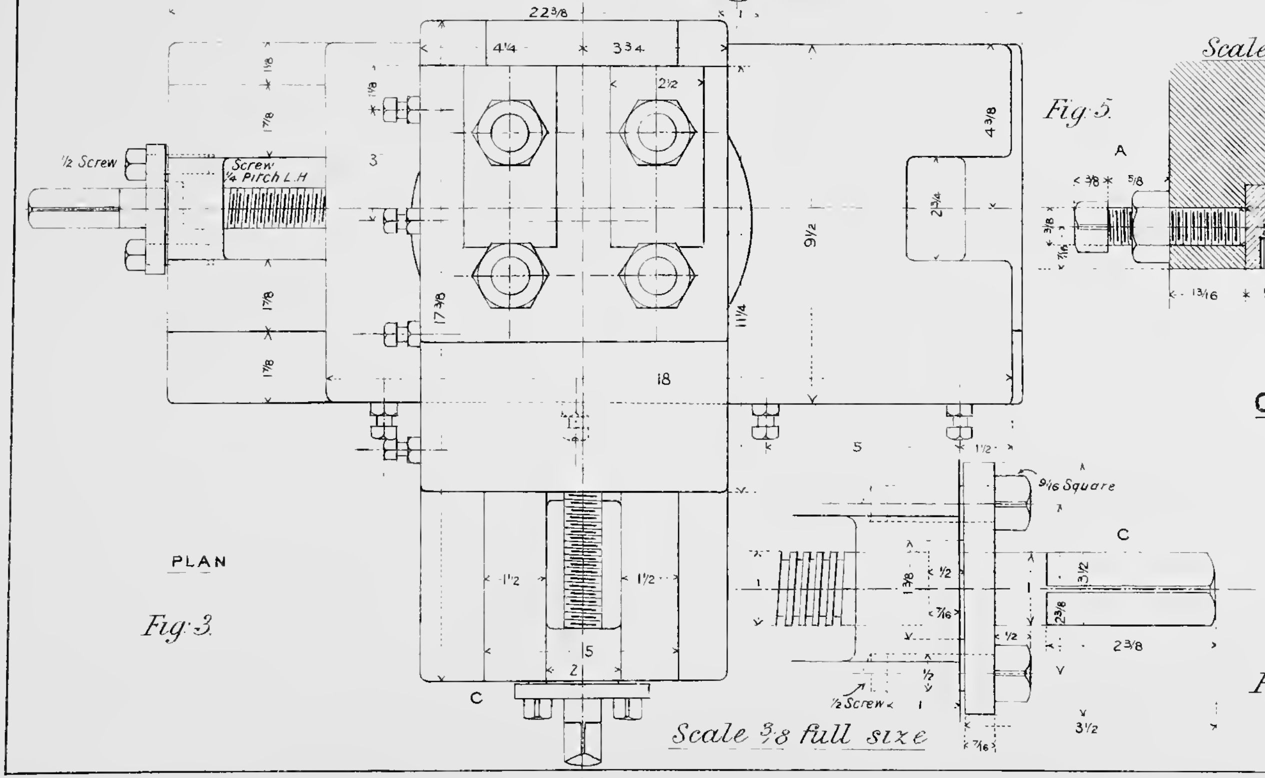
Fig. 2



PLAN

Fig. 3.

Fig. 4.



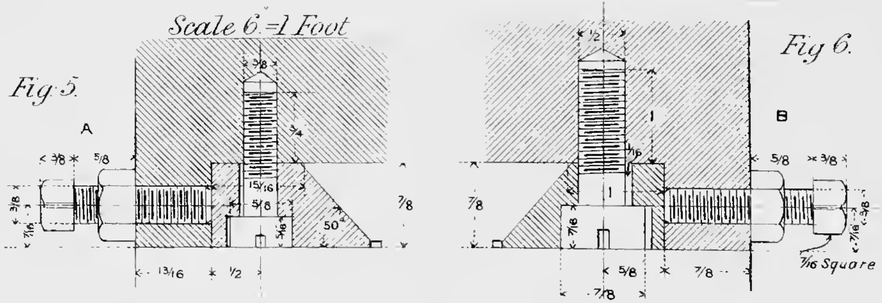
Scale ⅜ full size

ADJUSTMENT FOR V SLIDES.

Scale 6" = 1 Foot

Fig. 5.

Fig. 6.



COMPOUND HAND SLIDE REST

FOR 10" LATHE.

Scale ⅕ full size.

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Plate XXXVIII.—CYCLOIDAL AND INVOLUTE CURVES.

The following curves are used in the designing of wheel teeth: **Fig. 1. The Cycloid** is the path described by a point on the circumference of a circle, rolling upon a fixed straight line, in one plane passing through the line.

The base A B of the curve is equal in length to the circumference of the rolling circle, and may be obtained very approximately by the following construction: From C_5, the middle position of the centre of the rolling circle, draw the radius C_5 E, making an angle of 30° with the vertical radius, and draw E F perpendicular to that radius, meeting it in F. Through C_5 draw a line parallel to the base line, and mark off a length C_5G equal to three times the radius of the circle. Then $FG =$ half the circumference of the rolling circle $= AD = DB$.

Divide A B and the circumference of the circle into the same number of equal parts (say 8). The line through C_1 parallel to A D B, is the line described by the centre of the circle as it rolls upon A D B. From the points of division on A D B draw lines perpendicular to it, and intersecting the line of centres in the points C_1, C_2, C_3 - - - C_8, C_1.

Suppose the circle to start at C_1 and the describing point to be the point of contact. The positions of the point when the centre is at C_2, C_3 - - - are the points of intersection of the circles drawn from C_2, C_3 - - - as centres, with lines parallel to A B, drawn through the points 2, 3 - - - respectively.

Epi- and Hypo-cycloids. When a circle rolls upon the circumference of a fixed circle, the path of a point on the circumference of the rolling circle is called an Epi- or a Hypo-cycloid, according as the circle rolls upon the convex or concave side of the fixed one.

Figs. 2 and 3 show an Epi- and a Hypo-cycloid, the rolling circle and the fixed circle being 1″ and 3″ diameter respectively. Let O be the centre of the fixed circle, and B_5 and C_5 the centres of the moving circles in their middle positions. The curves subtend an angle of $\theta°$ at the centre O, which in this case is 120°.

For $OA \times \theta° = AB_5 \times 360° = AC_5 \times 360°$. $\quad \therefore \theta° = \dfrac{AB_5 \times 360°}{OA} = 120°$

Divide the arcs described by the centres of the rolling circles, and also the circumferences of these circles into any number of equal parts (say 8). The method of drawing the curves is shown clearly in the drawing.

When the diameter of the rolling circle is half that of the fixed circle, the hypo-cycloid is a diameter of the fixed circle.

Fig. 4. The Involute of a circle is the curve traced out by the end of an inextensible string unwound from a circle. The string is always a tangent to the circle from which it is unwound. Suppose the curve to start at the point 1. The length of the tangent, from its point of contact, to the curve, is equal to the length of the arc of the circle from the point of contact to the starting point. The normal to the curve, at any point, is the line passing through that point and tangent to the circle.

EXERCISES.

1.—Draw the cycloid when the rolling circle is $1\frac{3}{4}''$ diameter.

2.—Draw the Epi- and Hypo-cycloids, when the diameters of the rolling and fixed circles are $1\frac{1}{2}''$ and 4″ respectively. Show the special case of the Hypo-cycloid, when it is a straight line.

3.—Draw the involute of a circle of $1\frac{1}{2}''$ diameter for $\frac{3}{4}$ of a revolution.

WHEEL GEARING.

Toothed wheels are employed to communicate motion from one shaft to another, by direct contact. **Spur wheels** connect parallel shafts, and **bevel wheels** connect any two shafts whose axes intersect.

When two spur wheels, with teeth accurately shaped, are in gear, the angular velocity ratio is constant, and is the same as if they were friction wheels having the same centres. The surfaces of the imaginary friction wheels are called the **pitch surfaces** of the spur wheels; and a plane, at right angles to the axes of rotation, intersects these surfaces in circles, which are the **pitch circles.** The **pitch** of the teeth is the distance from the centre of one tooth to the centre of the next tooth, measured along the pitch circle. The diameter of the pitch circle, in terms of the pitch and the number of teeth, is expressed by

$d = \dfrac{nP}{\pi}$ where d = diameter of circle in inches.

P = pitch of teeth. „

n = number of teeth on wheel.

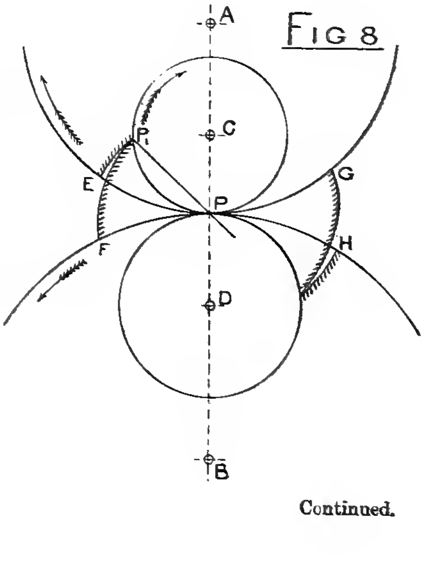
The dimensions of the teeth, in terms of their pitch, are given in **Fig. 5,** and are such that there is always contact between two or more teeth on each wheel in gear.

Fig. 6 shows a scale for determining the proportions for various pitches. The difference between the tooth thickness and the tooth space, measured on the pitch line, is the *side clearance.* The acting surface of a tooth, projecting beyond the pitch circle, is called its *face;* that inside the pitch circle, its *flank.* In all the examples given, the exact form of the tooth is determined, and the teeth afterwards set out by means of circular arcs, which are approximately coincident with the correct curves. In a drawing, where a wheel occurs to a small scale, the teeth may be drawn as shown in Fig. 5.

In order that wheels may work correctly together, and have a constant velocity ratio, it is necessary and sufficient that the common normal to two teeth, at the point of contact, always passes through the point of contact of the pitch circles. This condition is satisfied if the faces and flanks of the teeth are shaped to cycloidal or involute curves.

Cycloidal Teeth. Referring to Fig. 8, let A and B be the centres of two spur wheels, the pitch circles touching at the point P; C, the centre of a third circle, touching the other two at P. Suppose one of these circles to revolve round its centre, and cause the other two to turn round their centres in the directions shown.

FIG 8



Continued.

FORM & PROPORTION OF TEETH FOR WHEEL GEARING.

CYCLOID.

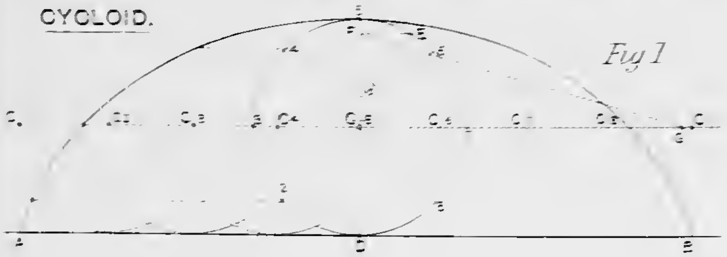


Fig 1

EPICYCLOID.

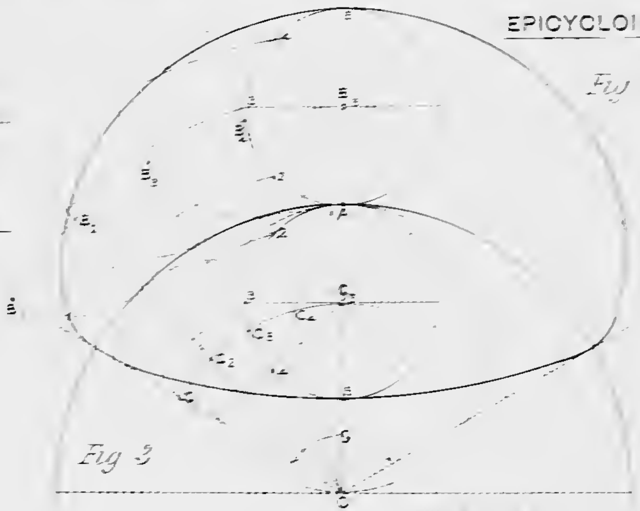


Fig 2

Fig 3

HYPOCYCLOID.

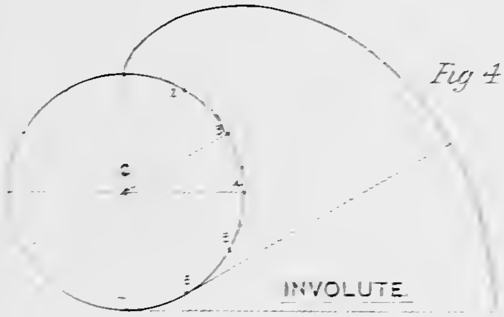


Fig 4

INVOLUTE.

PROPORTION OF TEETH.

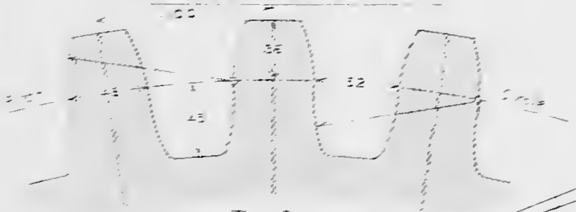


Fig 5

SCALE FOR PROPORTION OF TEETH.

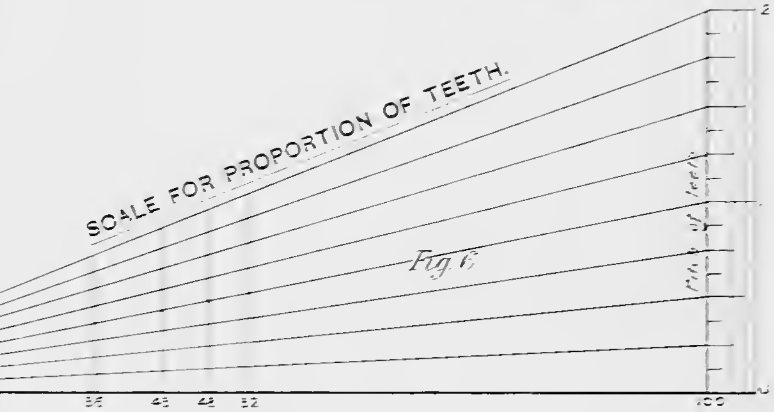
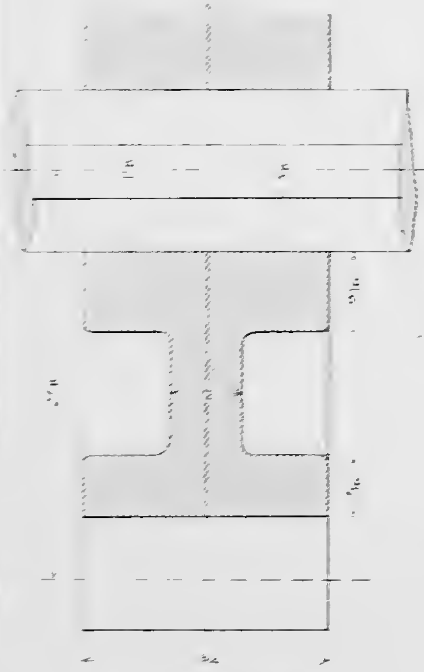


Fig 6

RACK AND PINION.

Scale 9"=1 Foot



SECTION OF PINION.

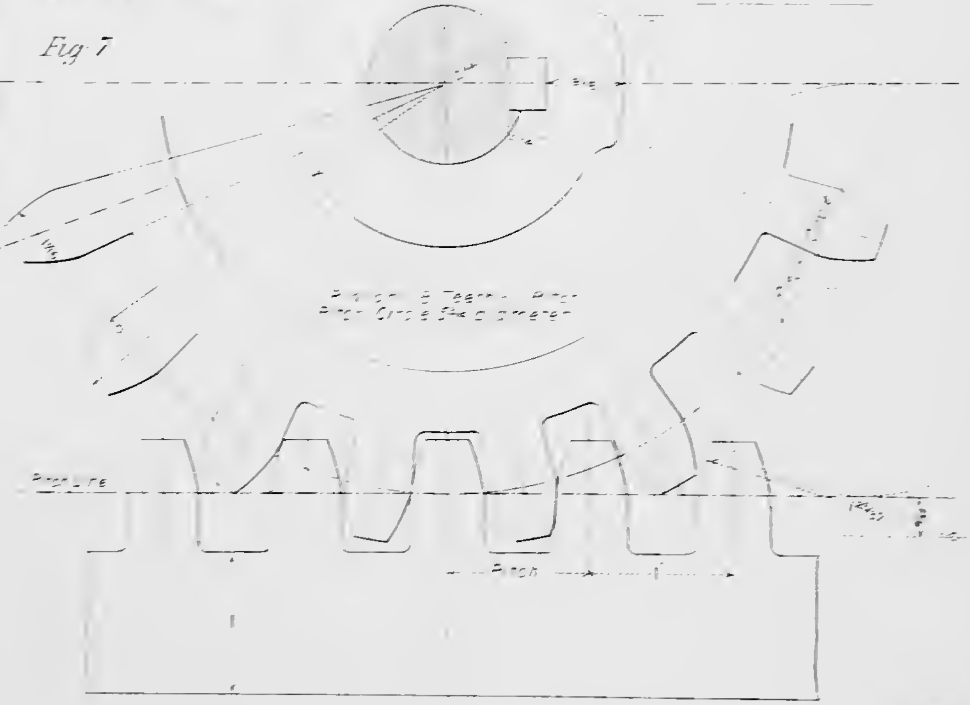

Pinion [illegible] Teeth [illegible] Pitch
Pitch Circle [illegible] diameter
Pitch Line
Pitch

Fig 7

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T.G. JONES.

Plate XXXIX.—WHEEL GEARING, *Continued.*

Take any point on the circumference of the circle **C**, and consider the curves traced out by it on the planes of the pitch circles **A** and **B**. Since the circle **C** rolls, relatively, on the inside of the circle **A**, the point will trace the Hypo-cycloid **E** P_1 on the plane of that circle. Again, the point describes the Epi-cycloid **F** P_1 on the plane of the circle **B**. If these curves, **E** P_1 and **F** P_1 be used as portions of the profiles of the teeth, they will remain in contact, since they are generated simultaneously by the same point; and the common normal at the point of contact will always pass through **P**.

The circle **C**, which is called a rolling circle, must therefore be used to generate the flanks of the teeth on wheel **A**, and the faces of the teeth on wheel **B**. A second rolling circle **D** generates the faces and flanks of the teeth on **A** and **B** respectively. The points of contact of the teeth are on the circumferences of the rolling circles.

Some amount of judgment is required in selecting the sizes of the rolling circles. For a train of wheels such as the change wheels for a lathe, where any two are to work together, the rolling circles are all equal in diameter to the radius of the smallest wheel. In this case, the teeth on the smallest wheel will have radial flanks, which are weak, since they are thinner at the root than at the pitch circle.

In the work-shop, the cycloidal curves are obtained by making templates having the same radii as the pitch circle and rolling circle respectively; and rolling one upon the other. The curve is traced out by a pencil placed in the edge of the template corresponding to the rolling circle.

Figs. 7 and 9. Rack and pinion. The rack may be considered as a wheel of infinite radius.

In this example, the pinion has radial flanks, and the rack, parallel flanks. Let the circle, Fig. 9, with centre **A**, be the pitch circle of the pinion, and the tangent at **P**, the pitch line of the rack. The circle, centre **B**, whose diameter is equal to the radius of the pitch circle, generates the hypo-cycloid **C** P_1 and the cycloid **D** P_1; **C** P_1 forms the flank of the tooth on the pinion, and **D** P_1 the face of the tooth on the rack.

Since the flanks on the rack are at right angles to the pitch line, they may be supposed to be generated by a point on the circumference of a circle of infinite radius, rolling on the line **D P**.

The faces of the teeth on the pinion are also to be generated by a point on this circle, and since it is equivalent to a straight line, the curve will be an involute.

Note.—The involute is the limit of the epi-cycloid, when the radius of the rolling circle is increased indefinitely.

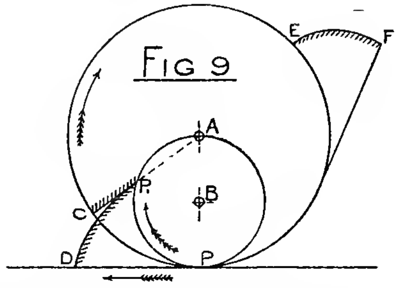


FIG 9

In drawing wheels, the pitch lines or circles are first described, and then divided accurately into as many parts as there are teeth on the wheels. The thickness and height above and below the pitch line of the teeth are determined for the particular pitch, from the scale on Plate XXXVIII.

Exercise.—Draw and complete the two views of the rack and pinion as given in Fig. 7, Plate XXXVIII, and add a plan. *Scale full size.*

Questions. 1.—Explain the terms, pitch, pitch circle, point, root, face and flank, as applied to wheel gearing.

2.—A spur wheel has teeth of 2″ pitch. Sketch a tooth and mark on it the thickness at the pitch line, and the height above and below the pitch line. What is meant by clearance of wheel teeth?

INVOLUTE TEETH.

Let **A** and **B**, Fig. 10, be the centres of the pitch circles of two spur wheels. Draw a line **C P D**, making an angle θ with the common tangent at **P**. With centres **A** and **B**, draw the two circles **K D L** and **M C N** respectively, tangent to **C P D**, at the points **D** and **C**. Let **S U** and **R T** be two involute curves described by flexible lines unrolling from the base circles **K D L** and **M C N** respectively, and touching at **Q**. These two curves have a common normal at the point of contact **Q**, which passes through **P**; therefore two such curves may be used as the profiles of the teeth. The working portion of the profile is one curve, and the part between the base circle and root circle is radial. The line **C D** is the path of contact, and in practice it is never inclined to the common tangent of the pitch circles at an angle greater than 15·5°.

Wheels with involute teeth, have the advantage over those with cycloidal teeth, in that they work equally well if the pitch circles do not exactly touch; and any wheels of the same pitch, and same inclination of the line of contact, will work together. The teeth of wheels used in mangles and calenders should be of this form. On Plate XXXIX two such wheels, **A** and **B**, are shown. The line of contact is inclined at an angle of 15·5° with the common tangent to the pitch circles. The involutes being drawn, circles are found having the same curvature for the length required for the teeth. For the wheel **A**, the approximate circular arc has a radius of 3″, the centre being $\frac{3}{8}''$ inside its pitch circle; again for **B**, the radius is $2\frac{1}{2}''$ and the centre $\frac{1}{4}''$ within the pitch circle. The student should draw out the involute curves, in order to see that the above arcs are sufficiently approximate.

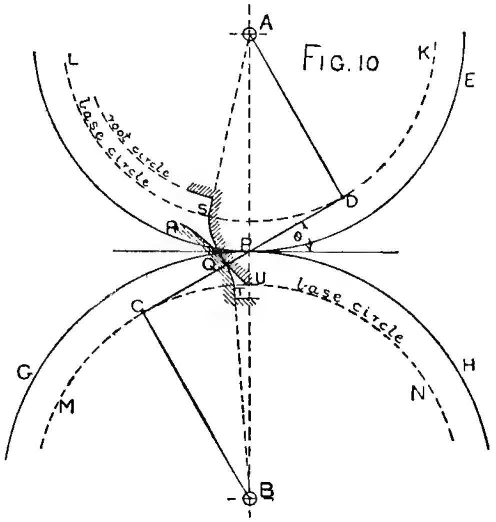


FIG. 10

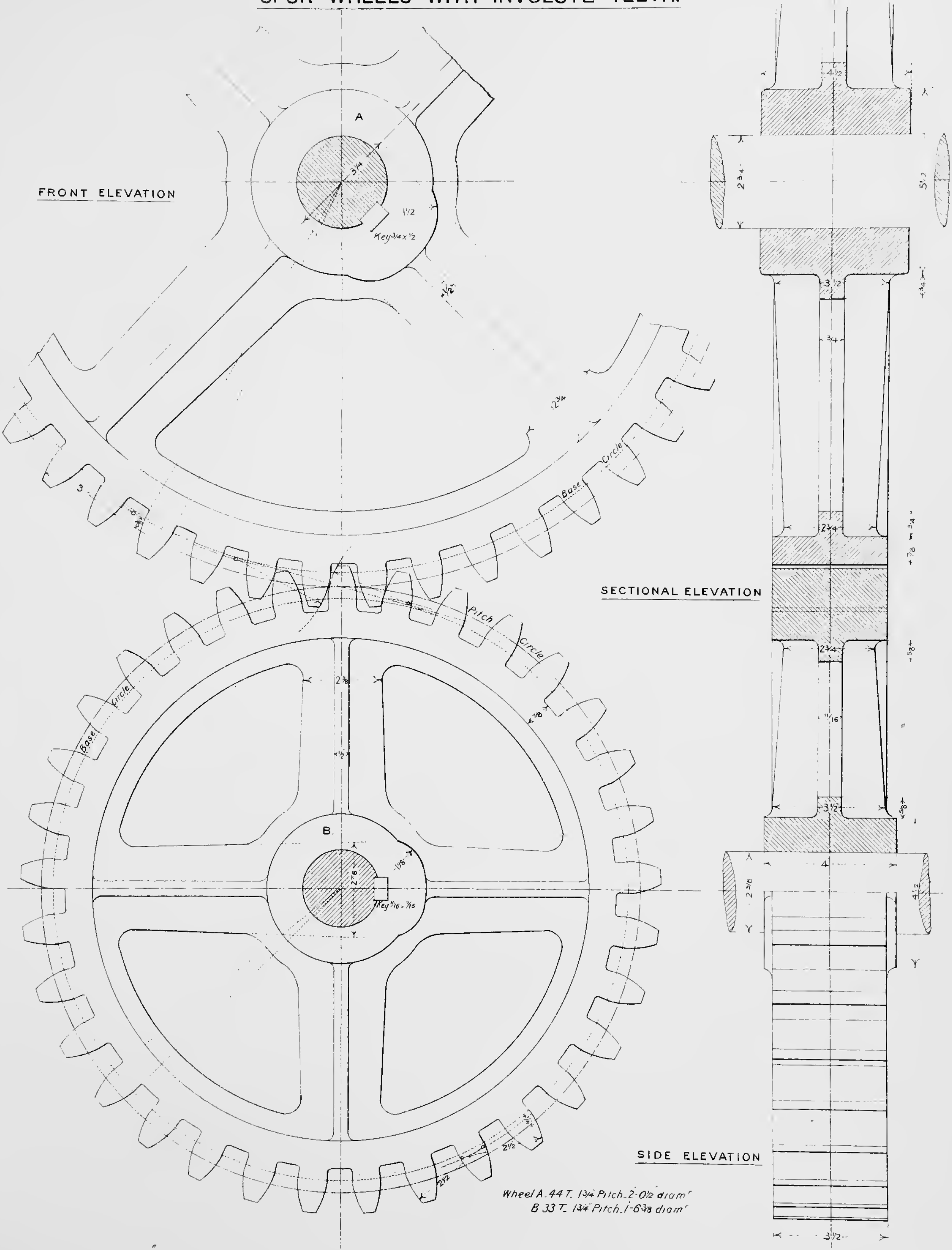
The arms of the wheels are made **+** section, but often the **H** section is used; the arms are then called face arms.

Exercise.—Draw and complete the given views of the spur wheels with involute teeth. *Scale 4″ = 1 foot.*

Question.—It is required to connect two shafts, which are to be as nearly as possible 4ft. apart, by spur wheels, so that the velocity ratio may be 4 to 1. Find the number of teeth in each of the two wheels, and the exact distance apart of the two shafts, the pitch of the teeth being 2″.

PLATE XXXIX

SPUR WHEELS WITH INVOLUTE TEETH.



Wheel A. 44 T. 1¾" Pitch. 2'-0½" diamr
B 33 T. 1¾" Pitch. 1'-6⅜" diamr

Scale 3" = 1 Foot

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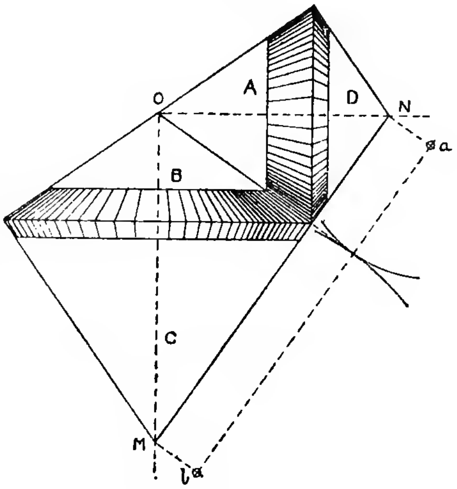
Plate XL.—BEVEL WHEELS,—CYCLOIDAL TEETH.

THE pitch surfaces of two bevel wheels in gear, are the frustra of two right cones which roll together. **A** and **B** represent two cones, having a common apex **O** at the point of intersection of the axes of the shafts. The bases of the cones are inversely proportional to the angular velocity ratio of the two wheels, and directly proportional to the number of teeth on them. The larger diameter and pitch are given as the diameter and pitch respectively of a bevel wheel. When two equal bevel wheels connect two shafts at right angles, they are called **Mitre Wheels.**



The teeth may be either cycloidal or involute, as in the case of spur wheels. The forms of the teeth are marked out on the surfaces of the cones **C** and **D**, whose generating lines are at right angles to similar lines on the pitch cones. All straight lines on the surfaces of the teeth radiate to the common apex of the pitch cones. The virtual pitch circles on which the teeth are described, are the bases of the cones **C** and **D** when developed. The line of centres **M N** is projected to *a b* for convenience.

In this example, the flanks of the teeth on the smaller wheel **A** are radial, so that the rolling circle, which generates the faces of the teeth on **B**, will be one, whose diameter is equal to the radius of the virtual pitch circle of **A**.

For the faces on **A**, and the flanks on **B**, a describing circle of $5\frac{1}{2}''$ radius is taken. The centres of the approximate circular arcs are on the pitch circles.

The arms of the wheels are of **T** section, and taper slightly towards the rim. On the drawing, the widths of the arms, if produced to the centre, are given. The sectional view of the wheels is drawn first, in order to determine the virtual and smaller pitch circles.

In the plan of **B**, the larger pitch circle is divided accurately into 45 parts, and a thin centre line drawn through each point.

The dimensions of the teeth, at the point and root, and also at the pitch circle, are then marked on the point, root, and pitch circles respectively, and all the points joined to the centre of the wheel.

Before drawing the plan of **A**, it will be necessary to draw a front elevation of it, and then project to the plan.

EXERCISE.

Draw the pair of bevel wheels in gear as shown, and add a front elevation of the wheel **A**. *Scale* $3'' = 1$ *foot.*

The exact shapes of the profiles of the teeth must be drawn.

QUESTIONS.

1.—Sketch, in section, a pair of bevel wheels in gear with one another. The centre lines of the shafts, and the form of the pitch surfaces of the wheels, are required to be carefully shown.

2.—Two shafts are inclined at an angle of 120° to one another, and it is required to connect them by bevel wheels, so that the velocity ratio may be 3 : 2. Draw the pitch cones of the required wheels, when the pitch is $1\frac{1}{2}''$ and the smaller wheel has 26 teeth.

3.—Obtain the cycloidal curves, as required for the teeth, on Plate XL., by means of cardboard templates.

4.—A spur wheel, 3 feet diameter, transmits 15 horse power when making 60 revolutions per minute. Find the pressure exerted at the pitch surface.

5.—Explain, by means of a sketch, the object of shrouding a toothed wheel. See pinions on Plate XXXV.

6.—Explain the effect of increasing the diameter of the rolling circle, which generates the flanks of the teeth on a wheel.

7.—Give a section of the rim of a mortice bevel wheel, and explain how the teeth are fitted.

BEVEL WHEELS WITH CYCLOIDAL TEETH.

Scale 1¾″=1 Foot.

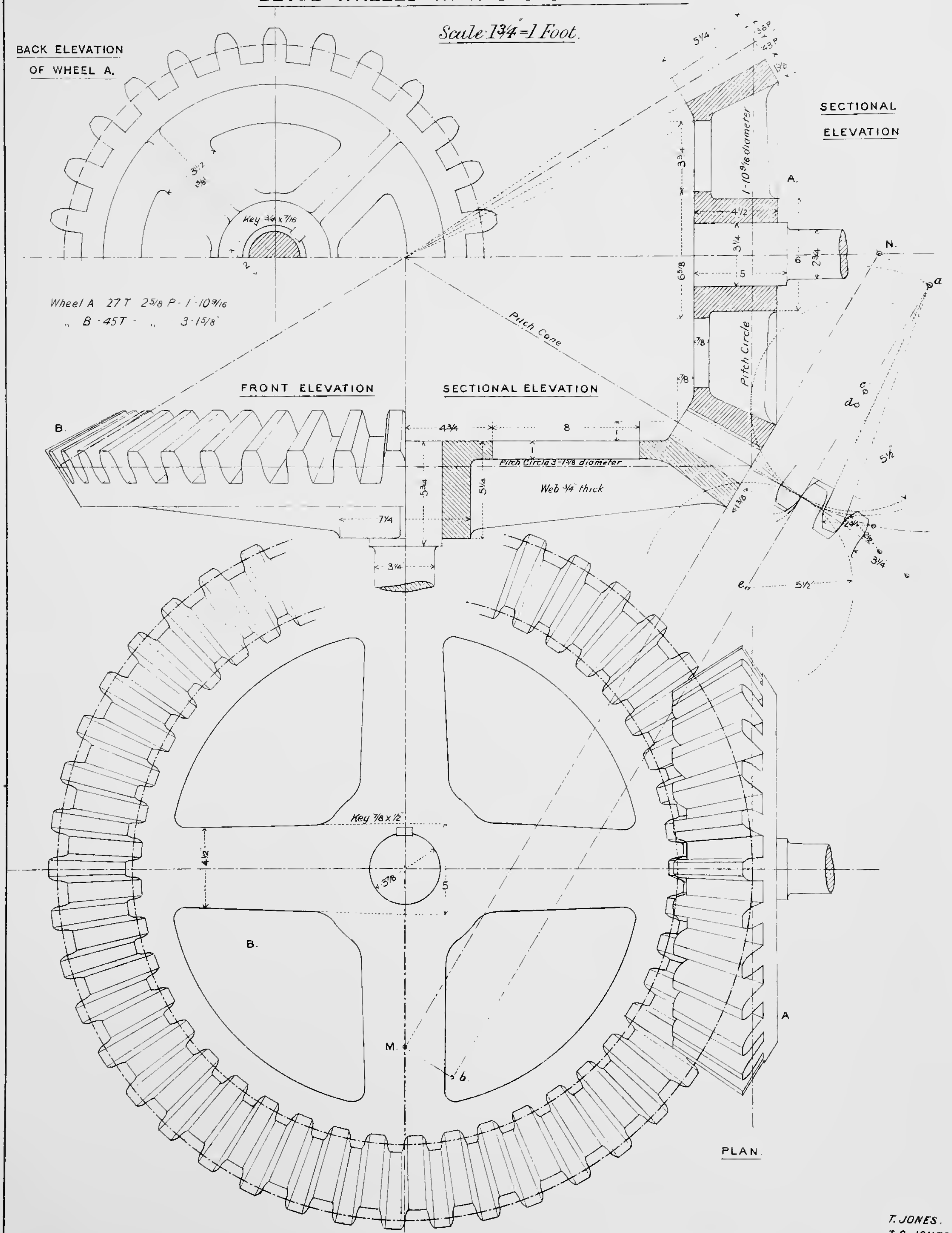


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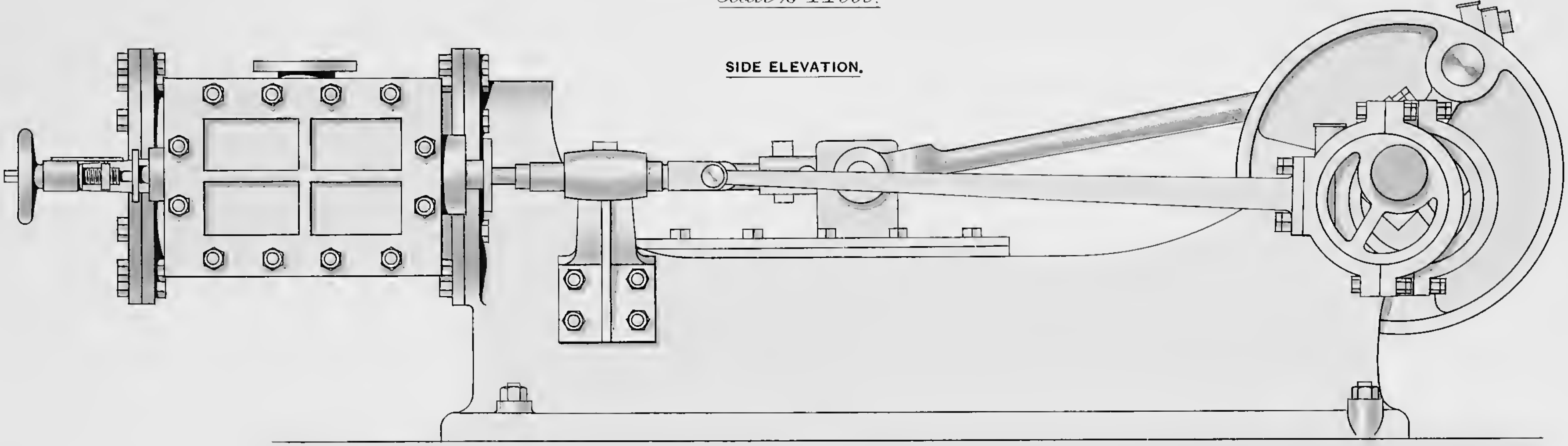
PLATE XLI.

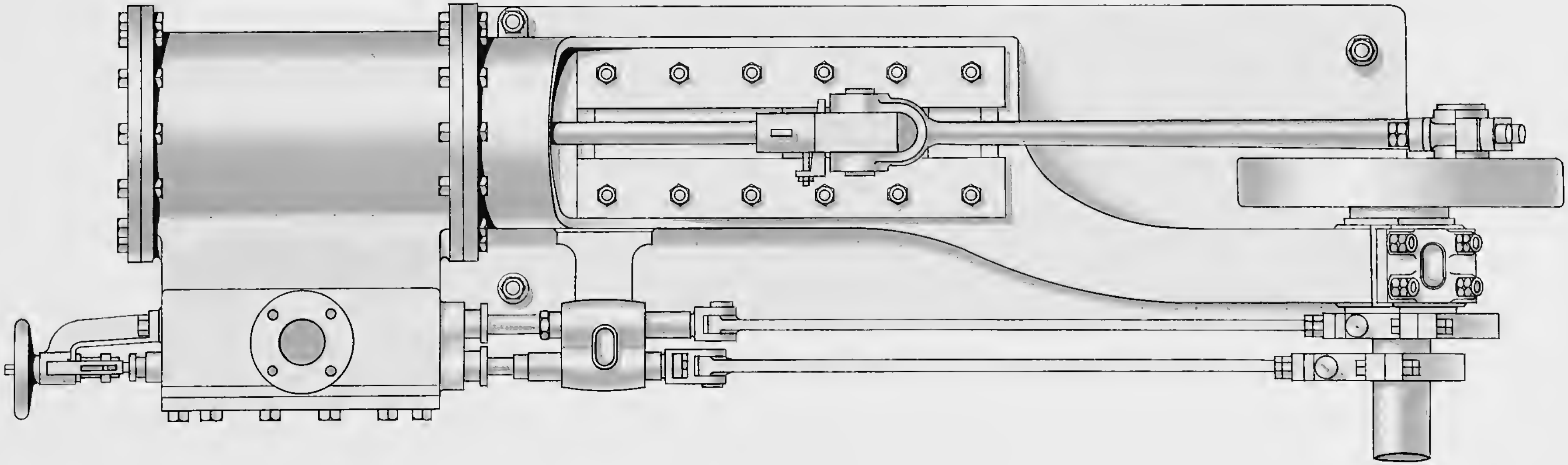
HORIZONTAL ENGINE WITH VARIABLE EXPANSION GEAR.

Scale 7/8" = 1 Foot.

SIDE ELEVATION.



PLAN.



NOTE.—For dimensioned details, see Plates Nos. 18, 21, 27, 29, 31 42, 43 and 44.

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SUPPLEMENT

TO BOOK I.

MACHINE DRAWING,

By T. JONES and T. G. JONES.

LIST OF PLATES.

Plate XLI.—**COLOURED DRAWING** of a Small Horizontal Engine.
„ XLII.—Detail of Engine Bed, Partly in Section.
„ XLIII.— „ „ Cylinder, Valve Rods, &c.
„ XLIV.— „ „ Crosshead, Connecting Rod, Fly-wheel, &c.
„ XLV.—Complete Drawing of a "Pickering" Governor.

THE drawings on the above-named plates, together with those given in the earlier portion of the book, are such as will enable the student to draw completely a single cylinder, non-condensing horizontal engine, fitted with Meyer's variable expansion valve gear, and having the cylinder steam jacketted.

Only the drawings of parts which differ widely in design and scale from those previously given are fully dimensioned. In all other cases the most important dimensions only are given, and reference is made to details of similar design. To advanced students the completing of the drawings should present no serious difficulty, but at the same time will allow of the exercise of individual skill in proportioning some of the minor details.

ENGINE BED. PLATE XLII.—The engine bed is a hollow cast-iron frame of $\frac{3}{4}''$ metal, and with it are cast the front cover of the cylinder with stuffing box, the bottom slide for crosshead, and the crank shaft bearing. It is secured to the foundation by five $1\frac{1}{8}''$ cotter bolts. See Plate VIII., Fig. 3.

The crank shaft bearing is inclined at an angle of 45° so that the maximum pull or thrust of the connecting rod—which is approximately horizontal—is resisted by the most substantial part of the step. Four $\frac{7}{8}''$ stud bolts are used to hold down the cap. The dimensions of the stuffing box for the piston rod are given on Plate XXIX., Fig. 1.

STEAM CYLINDER. PLATE XLIII.—The cylinder, which overhangs the bed, is secured to its end by bolts and studs. The liner is made of close grained cast iron, and is slightly tapered on the outside; it is driven into position in the cylinder from the back end.

The space between the liner and the cylinder body forms the steam jacket, which is supplied with "live" steam. The condensed steam is drained from the jacket by means of a steam trap. The function of the jacket is the prevention of excessive condensation of steam in the cylinder during admission and early expansion.

In this engine the steam chest is nearly as long as the cylinder. This is caused by using Meyer's variable cut-off valves to effect the steam distribution. To shorten the external length of the chest the vertical flanges are cast on the inside. The steam is supplied through a $3\frac{1}{2}''$ pipe and exhausted through a $4''$ pipe.

SLIDE VALVES AND RODS. PLATE XLIII.—For the **design** of the main and expansion valves see Plate XXXI..

The **Main** valve is $3\frac{1}{2}''$ deep, and the two steam passages—each $1\frac{1}{4}''$ wide—are at **right angles** to the face of the valve. Its dimensions, as affecting the steam distribution, are as follow:—For the forward stroke of the piston: steam lap $1\frac{1}{4}''$, exhaust lap $\frac{1}{4}''$, lead $\frac{1}{8}''$; for the return stroke: steam lap $1\frac{3}{16}''$, exhaust lap $\frac{1}{4}''$, lead $\frac{3}{16}''$.

Each expansion plate is 3½″ wide across the face. By regulating the distance between their outer edges, the steam may be cut off at any part of the stroke earlier than that due to the main valve alone, which effects the **cut off at 0·75 of forward stroke and 0·7 of return stroke.**

The method of changing the point of cut off during the running of the engine is explained in the text to Plate XXXI.

The valve rods outside the steam chest are enlarged by their connection with wrought-iron cylindrical guides, which have forked ends for attachment to the eccentric rods. These guides are supported by a cast-iron bracket fixed to the side of the engine bed.

ECCENTRICS AND RODS.—See Plate XXI., Fig. 2, for design of an eccentric. For this engine the main dimensions are as follow:—Width of eccentric sheave and strap, 2″; boss, 2¼″ through; eccentricity, 2½″.

The **T** end of each eccentric rod is 6½″ long × 2″ wide; each is fixed to an eccentric strap by two ⅞″ studs 4¼″ apart. The section of the rod at the strap end is 2½″ × 1″, and that at the valve rod end 1¼″ × 1″.

The eccentric for the main valve has an angular advance of 34°, and that for the expansion valve is placed diametrically opposite to the crank.

PISTON.—See Plate XXVII., Fig. 3, for details of 12″ piston.

DISC CRANK.—For design see Plate XX., Fig. 3. The disc is 4″ across the rim, 2′—2½″ outside diameter, and 5″ through the boss.

The crank pin is of steel 3¼″ diameter × 4″ long between the collars. The disc is shrunk to its end, and the pin further secured by means of a key.

CONNECTING ROD. PLATE XLIV.—This rod is five times the length of the crank, and is of the same type as that given on Plate XXIII. It is made of hammered scrap iron or steel.

CROSSHEAD. PLATE XLIV.—The crosshead is of wrought iron and provides a substantial bearing area against the slides. The tapered end of the piston rod is secured to it by a steel cotter. The brasses are flush with the sides of the crosshead, and are fitted with a taper key for their horizontal adjustment.

CRANK SHAFT. PLATE XLIV.—The shaft is of steel 4½″ diameter, bossed to 5½″ where the fly-wheel is keyed on. Bearings, 4″ diameter × 7½″ long. The outer end of the shaft should be carried by a pedestal, bolted either to a cast-iron standard fixed to the foundation, or to a wall-box, similar to the one shown on Plate XIV., if the engine be placed near a wall.

FLY-WHEEL. PLATE XLIV.—The fly-wheel is cast in one piece, but the boss is divided into three parts so as to minimise the internal stresses due to irregular cooling after casting.

The boss is held together by two steel rings shrunk on, one on each end of it. The power of the engine is transmitted through the fly-wheel by means of a belt. The width of rim = 12″ for a belt 10″ to 11″ wide. By the rough approximate rule for horse power of belts given in the text to Plate XVII., a 10″ belt working on a pulley 7′ diameter at a speed of 90 revolutions per minute will transmit 37·8 horse power.

To determine the maximum indicated horse power of the engine, [see text to Plate XXX.].

Gauge pressure at steam chest taken at 45 lbs. per square inch—

$$H = \text{indicated horse power of engine} = \frac{2\,A\,P_m\,R\,S}{33000}.$$

A = area of 12″ piston = 113 square inches.

P_m = **mean** effective steam pressure = 41·9 lbs., say 42 lbs. per square inch (see note below).

R = number of revolutions per minute = 90.

S = stroke in feet = $\frac{20}{12}$.

$$H = \frac{22 \times 113 \times 42 \times 90 \times 20}{33000 \times 12} = 43{\cdot}14 \text{ theoretical horse power.}$$

The actual indicator diagram is always smaller than the theoretical one. This loss of area is allowed for by using a **diagram factor.** Taking this factor as ·85 then 43·14 × ·85 = **36·6** = probable I. H. P.

NOTE.—The mean effective steam pressure P_m may be found by the formula. $P_m = P_1\left(\frac{I + H}{R}\right) - P_b$ where:—

P_1 = gauge pressure of steam in the steam chest + 15 lbs. for atmosphere = 60 lbs. absolute.

R = ratio of expansion = $\frac{4}{3}$; steam being cut off at $\frac{3}{4}$ stroke.

H = hyperbolic log. of R = ·285, and P_b = back pressure = say 16 lbs.

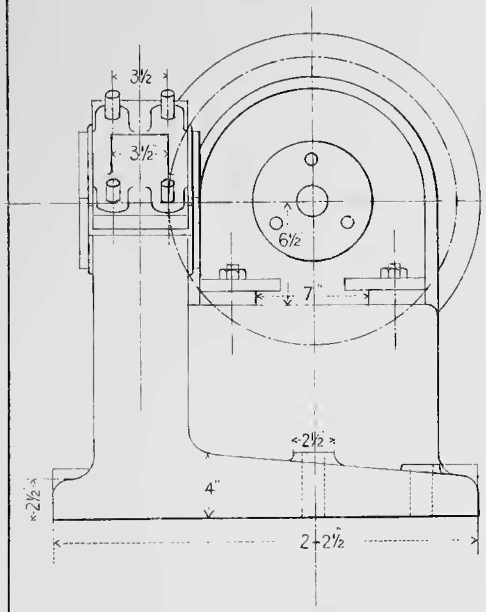
$$\text{Then } P_m = 60\left(\frac{1 + {\cdot}285}{\frac{4}{3}}\right) - 16 = 41{\cdot}9 = \text{say } 42 \text{ lbs.}$$

DETAILS OF 12"×20" HORIZONTAL ENGINE.

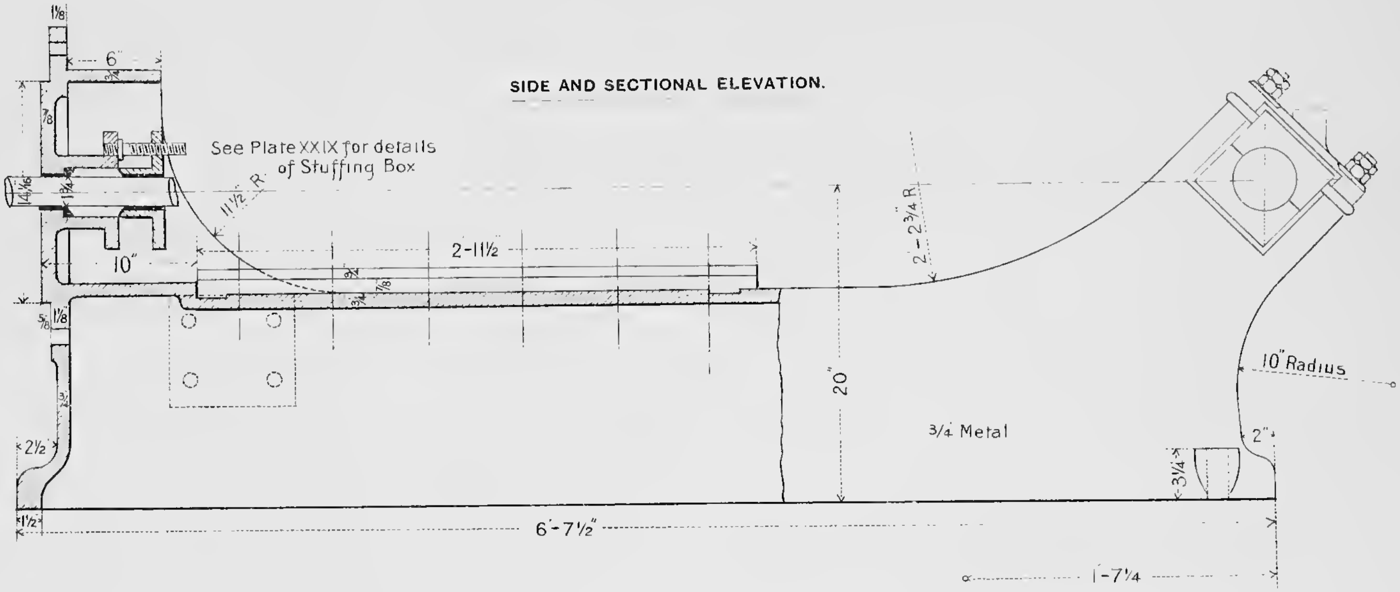
ENGINE BED.

Scale 1" = 1 Foot

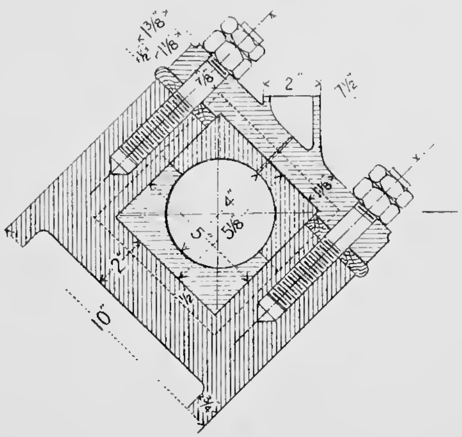
END ELEVATION.



SIDE AND SECTIONAL ELEVATION.

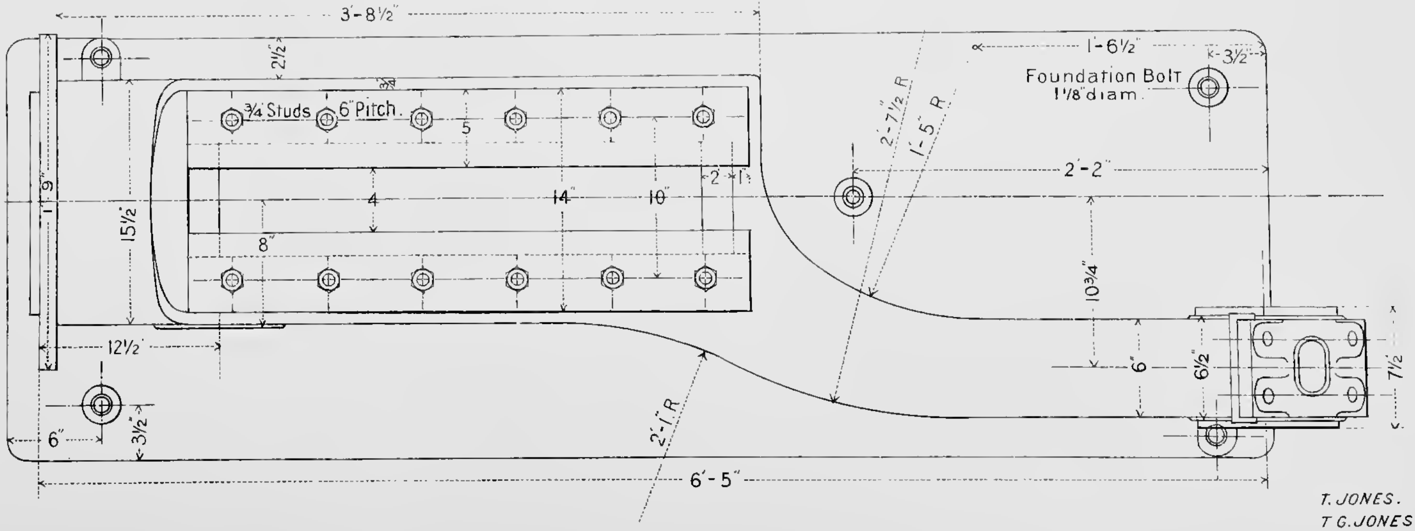


SECTION OF BEARING.



Scale 1¾" = 1 Foot

PLAN.



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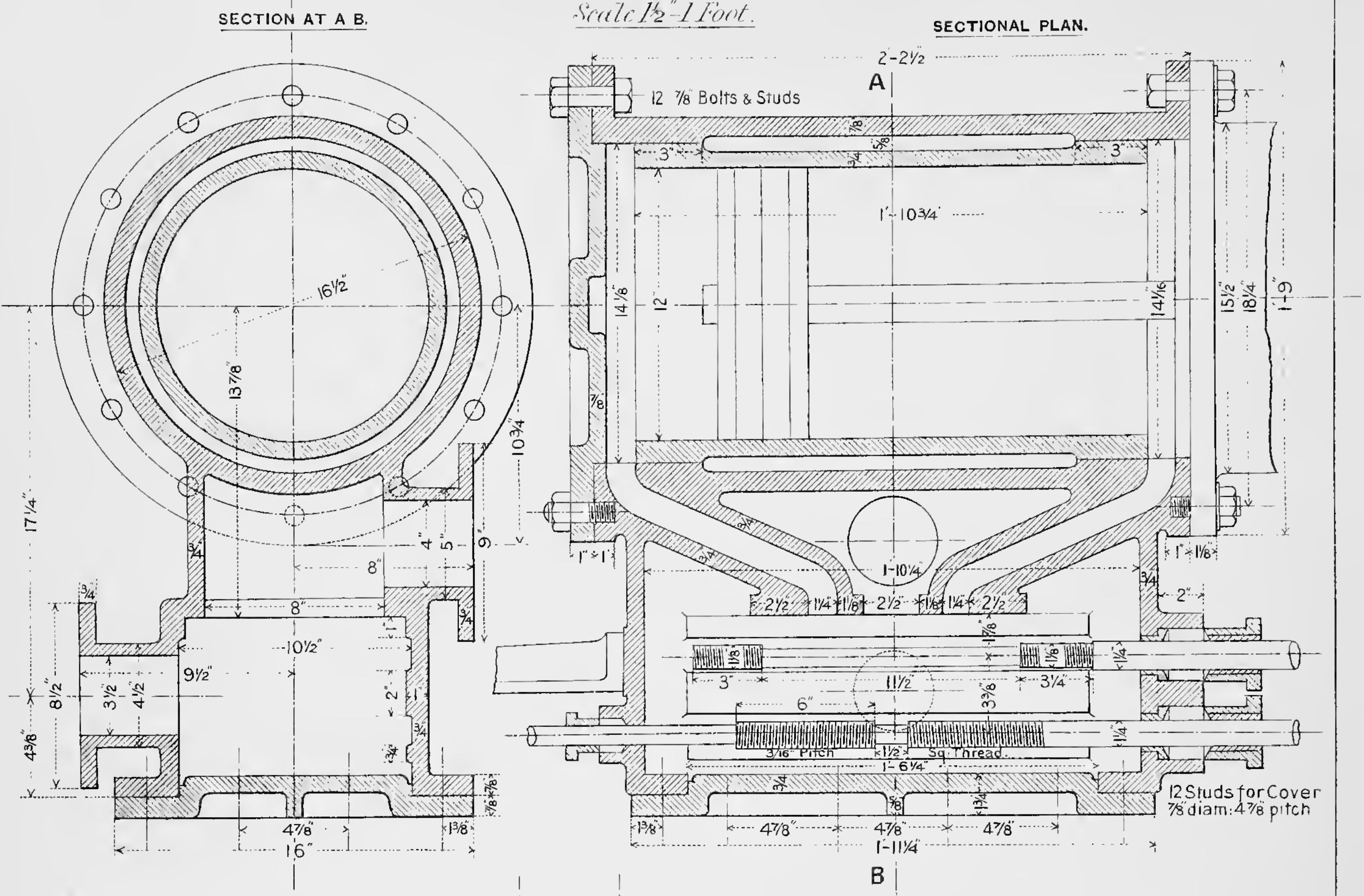
DETAILS OF 12"×20" HORIZONTAL ENGINE.

ENGINE CYLINDER.

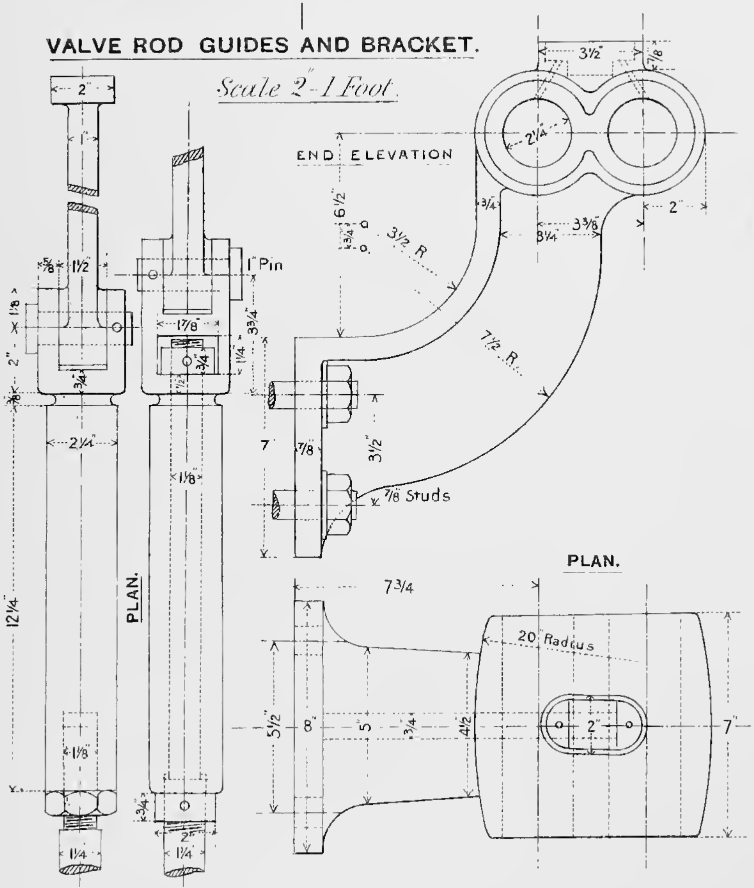
Scale 1½"–1 Foot.


SECTION AT A B.

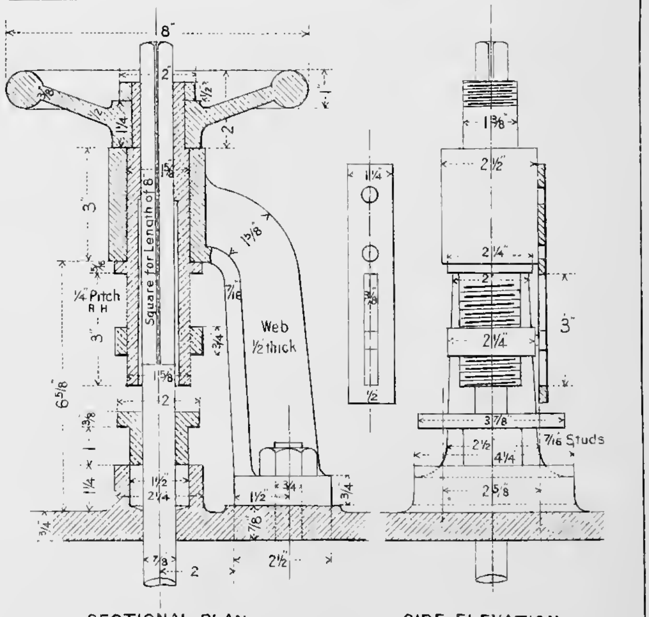
SECTIONAL PLAN.

VALVE ROD GUIDES AND BRACKET.

Scale 2"–1 Foot.



ADJUSTING ARRANGEMENT FOR EXPANSION PLATES OF OUT-OFF VALVE.


SECTIONAL PLAN.

SIDE ELEVATION.

Scale 1/5 full size.

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DETAILS OF 12"×20" HORIZONTAL ENGINE

CONNECTING ROD AND CROSSHEAD.

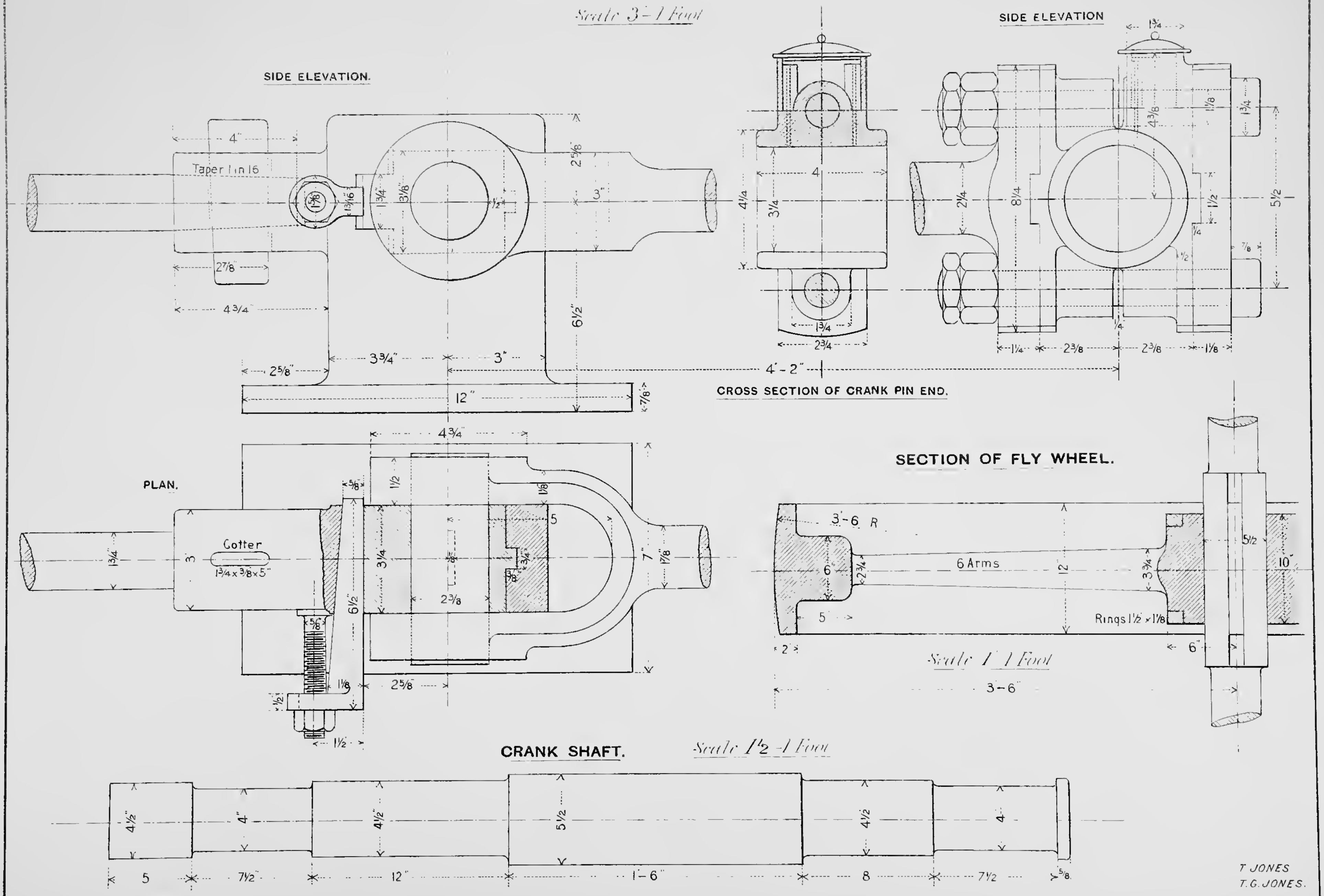

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Plate XLV.—PICKERING GOVERNOR.*

THE Pickering Governor is one of the simplest and most efficient of high-speed governors, and is, in consequence, extensively used on all classes of land engines.

The one of which details are given is for a 6″ steam supply pipe, and is suitable for an engine with cylinder about 30″ diameter.

The three cast-iron balls **F** are fixed to flat steel springs whose ends are attached to two discs carried by the tubular spindle **J.** The lower disc is free to rotate round the tube, which is driven tightly into the boss of the small standard, but the disc is prevented from rising by a collar fixed on the tube.

Motion is given to the balls through the lower disc by means of the mitre wheels **E** and **D**; the former being fixed to the disc by set screws, and the latter to the spindle upon which the driving pulley is keyed.

The upper disc is free both to rotate and to rise and fall on the tube, and being connected to the valve spindle **S** as shown, only its vertical motion is transmitted to the equilibrium valve **TV.**

The supply of steam to this valve is regulated by the steam stop valve **SV,** which is placed in the horizontal branch **A.** The varying amount of steam which is required to minimise the fluctuation of the speed of the engine passes to the steam chest through the valve **TV.**

It is clear that the greater the speed of rotation of the balls, the greater will be the deflection of the springs and the smaller the opening for the steam through the equilibrium valve.

The normal speed for this size of governor is 275 revolutions per minute, but it may be altered within small limits by means of the helical spring acting upon the arm **K** which fits into a slot in the valve spindle. The arm is carried by a small horizontal spindle which supports the helical spring. One end of the spring fits into the boss of the arm, and the other end into the boss of a worm wheel. The worm wheel is driven by a worm, and by its action in twisting the helical spring, the controlling force exerted by the flat springs on the balls may be increased or diminished according as the arm exerts an upward or downward pressure on the spindle.

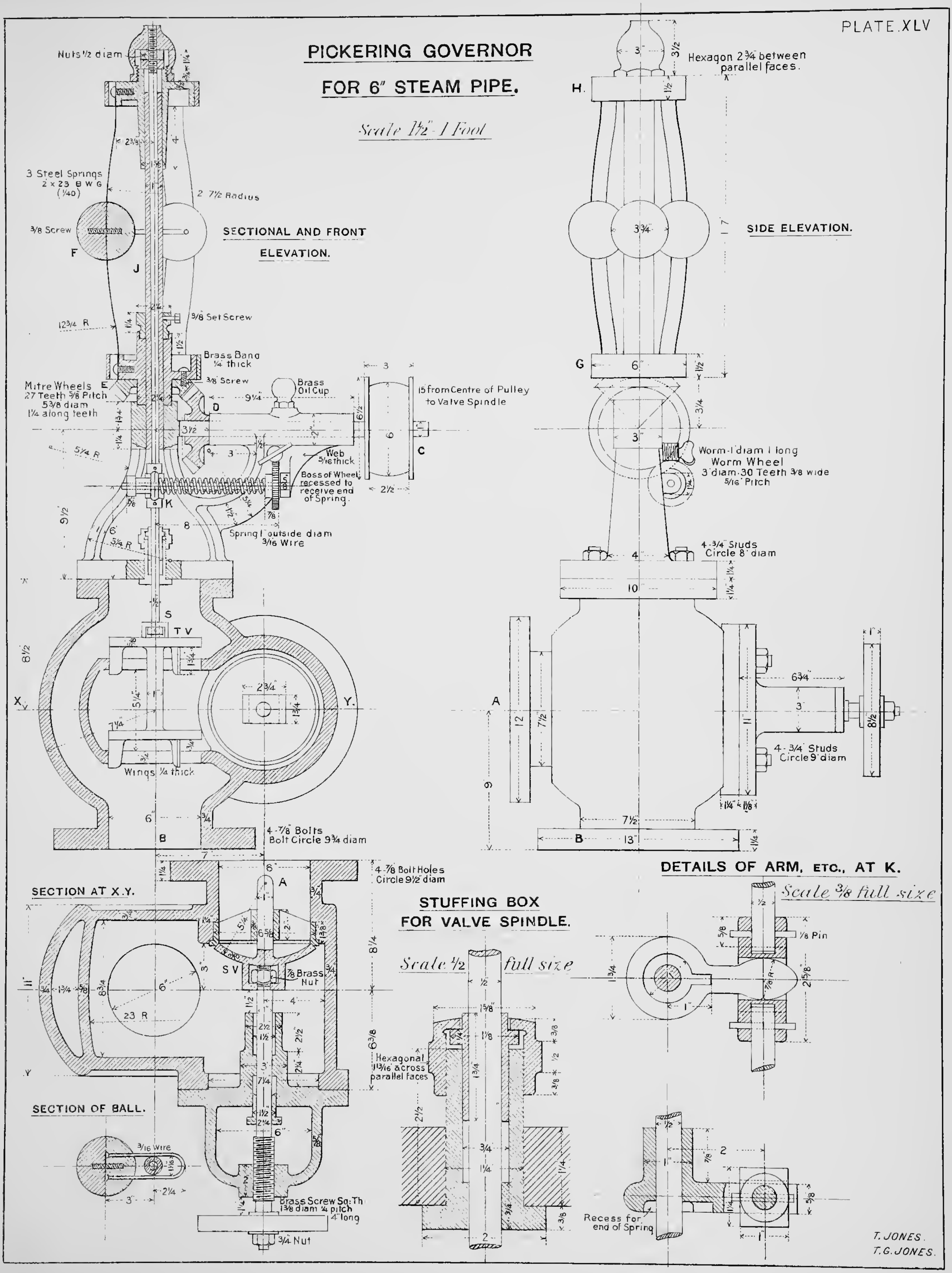
In consequence of the connection of the balls with the valve, without the intervention of any joints, the governor works with very little friction, and is therefore sensitive to small variations of speed.

---

* This drawing has been made from one supplied by Messrs. Stocks & Co., Manchester.

PICKERING GOVERNOR FOR 6″ STEAM PIPE.

Scale 1½″ - 1 Foot



SECTIONAL AND FRONT ELEVATION.

SIDE ELEVATION.

SECTION AT X.Y.

SECTION OF BALL.

STUFFING BOX FOR VALVE SPINDLE.

Scale ½ full size

DETAILS OF ARM, ETC., AT K.

Scale ⅜ full size

Nuts ½ diam
3 Steel Springs 2 x 23 B W G (1/40)
2 7½ Radius
⅜ Screw
F
J
12¾ R
⅜ Set Screw
Brass Band ¼ thick
⅜ Screw
Mitre Wheels 27 Teeth ⅝ Pitch 5⅜ diam 1¼ along teeth
E
D
Brass Oil Cup
15 from Centre of Pulley to Valve Spindle
C
Web 5/16 thick
Boss of Wheel recessed to receive end of Spring.
K
Spring 1″ outside diam 3/16 Wire
5¼ R
S
T V
X.
Y.
Wings ¼ thick
B
4-⅞″ Bolts Bolt Circle 9¾ diam
H.
Hexagon 2¾ between parallel faces.
G
Worm - 1″ diam 1 long
Worm Wheel 3″ diam - 30 Teeth ⅜ wide 5/16″ Pitch
4-¾″ Studs Circle 8″ diam
A
4-¾″ Studs Circle 9″ diam
4-⅞ Bolt Holes Circle 9½″ diam
A
S V
⅞ Brass Nut
23 R
3/16 Wire
Brass Screw Sq. Th 1⅜ diam ¼ pitch 4″ long
¾ Nut
Hexagonal 1 13/16 across parallel faces
⅛ Pin
Recess for end of Spring

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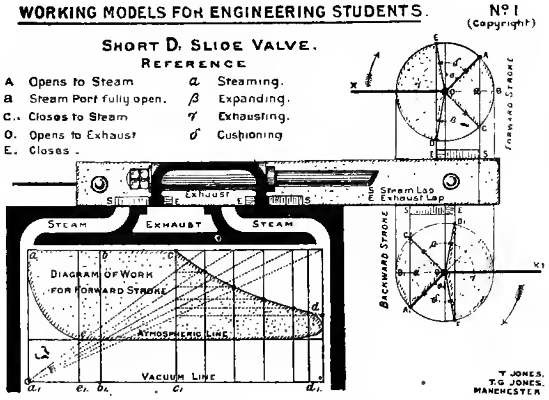

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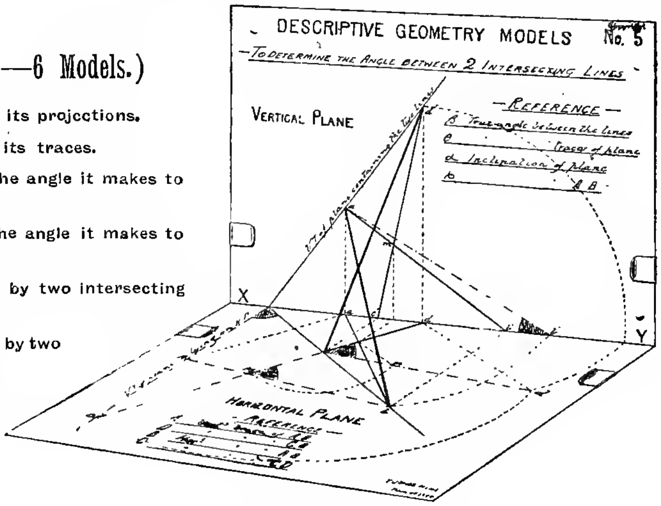
6.—The angle contained by two intersecting planes.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e Traces of plane
α Inclination of plane
b AB
V.T. of plane containing the two lines
X
Y
Horizontal Plane
—Reference—

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